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ABSTRACT

The intent of this document is to provide answers to questions related to teaching the metric system. Topics covered include: (1) A Model for Developing Understanding and Skills in Measurement; (2) Metric Measurement Units; (3) SI Do's and Don'ts; (4) Examples of Everyday Uses of SI Measures; (5) Child Development and Learning to Measure; (6) Choosing Instructional Material and Equipment; (7) A Minimal List of Metric Equipment and Materials; (8) A Desirable List of Metric Equipment and Materials; (9) Metric Equipment and Materials You Can Make; (10) Activities and Games; (11) A Brief History of Metric Measurement and Legislation; (12) A Guide for Writing Learning Sequences in Measurement; and (13) Activities to Involve the Community. (MP)

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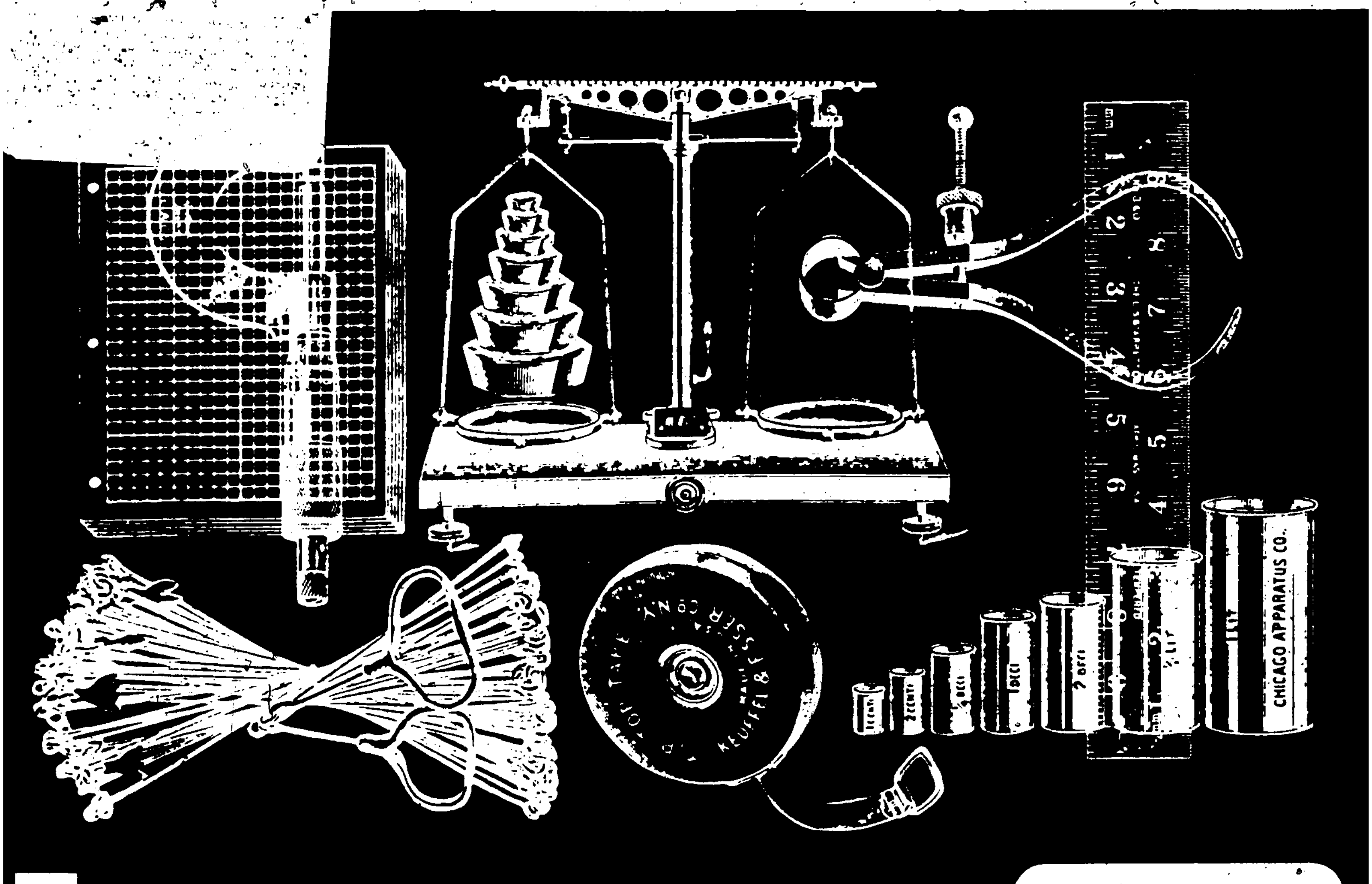
TEACHER RESOURCE GUIDE for METRIC EDUCATION



MICHIGAN DEPARTMENT OF EDUCATION

Foreword

Bicentennial Horizons Goal

On December 23, 197: President Ford signed the "Metric Conversion Bill." The question no longer is whether metric but when and how.

In 1973 the State Board of Education passed a resolution stating that all mathematics and science textbooks adopted after June 1976, should contain the SI (metric system) as the dominate system of measure. Since that time, Department of Education staff have been working toward implementation of metric education in Michigan schools beginning with the 19 school year. As a first step in the implementation procedure, the Department of Education distributed minimal performance objectives for metric education to Michigan school districts.

The following document, prepared and distributed as the Bicentennial Horizon Goal Project for the Department of Education, is intended to provide answers to the "how-to-teach-metric" questions. The National Bicentennial Horizons Goal is to improve the quality of American life in the United States' third century, and a program of quality metric education in Michigan schools will help accomplish that goal for Michigan citizens.

I would like to thank the members of the Metric Education Resource Group for their efforts in preparing this document. I hope that educators in Michigan will find the guidelines, suggestions, and resources contained herein helpful in making "Think Metric in Michigan" a reality.

John W. Porter
Superintendent of Public Instruction

Acknowledgments

The Metric Education Referent Group has functioned through a committee structure. Although there has been a great deal of inter-group communication and exchange of ideas, each committee has concentrated on a single area of concern. This publication is the product of one of those groups, the Guidelines Subcommittee. Editing of the publication has been done by: Jean Grey, Julian Brandou and Wayne Scott. Judy Bauer has coordinated the activities of the subcommittees. Committee membership (1975-76) was:

Joseph Baker	Saginaw News
Rosella Bannister	Eastern Michigan University
Judy Bauer	Michigan Department of Education
Julian Brandou	Michigan State University
Rita Brey	Detroit Public Schools
Peg Brown	Holt Public Schools
Donald Buckeye	Eastern Michigan University
Rose Burleson	Bullock Creek Public Schools
Art Coxford	University of Michigan
James Dulworth	Grand Ledge Public Schools
Douglas Gill	Saginaw Steering Gear
LaBarbara Gragg	Wayne Intermediate School District
Jean Grey	Saginaw Public Schools
Herbert Hannon	Western Michigan University
Russell Hastings	Clark Equipment Company
Dianne Hewitt	Traverse City Public Schools
Monte Higgins	Central Michigan University
Betty Hildebrand	Wayne-Westland Community Schools
Kenneth Hill	Detroit Public Schools
Richard Kahle	Romulus Community Schools
Dennis Kelly	Saginaw Intermediate School District
Don Kittilsen	East Lansing Public Schools
Perry Lanier	Michigan State University
Philip Larsen	Western Michigan University
John Lindbeck	Western Michigan University
Fran Loose	East Lansing High School
Gail Nordmoe	Detroit Public Schools
Oliver Oberlander	Central Michigan University
J. Michael O'Connor	St. Johns Public Schools
William Oosse	Grand Rapids Public Schools
Mary Reed	Benton Harbor Public Schools
Kathy Savage	Wayne-Westland Community Schools
Wayne Scott	Michigan Department of Education
Albert Shulte	Oakland Schools
Larry Starr	Interlochen Arts Academy
Sally Swartz	East Lansing Public Schools
Benjamin Webb	Saginaw Township Schools
Robert Williams	General Motors
Opal Wong	East Lansing Public Schools
Lauren Woodby	Michigan State University
Tom Yack	Wayne-Westland Community Schools

A special word of thanks is extended to all of these people who have given of their time and talents to further metric education in Michigan.

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A Model for Developing Understanding and Skills in Measurement

The Internationa stem measureme gradually replacing the c.. stomary and familiar collection of measures in Americ : is important that the implementation programs of metric education in Michigan schools. T is no longer an on about whether we should or should not metric, the questions are "How should we when should we start?"

The individual classroom teacher decision-maker for curriculum. Decisions involving the selection of lessons, the sequencing and adaptation to individual learners, the materials available, the time allowance and a host of other factors considered by the teacher as daily instruction is planned. These guidelines do not specify a complete series for all teachers everywhere. Instead framework is suggested for development practical sequential activities for learning to measure using SI units. Goals and objectives will be considered fo and specific activities will be described for each grade.

The older student the adult learned to measure many quantities. For these learners metric education introduces a new set of units and the conversion of old estimation habits to the units. For the younger learner me measurement using the SI units and objects of appropriate dimensions may be taught immediate When young learner encounters residual customary measures measures will be related the metric sizes.

Preparing learners eal effectively a metric world will require some changes in the way measurement is taught. Neither the teaching the learning will be difficult, and the nature of metric units is such that the teaching can be more systematic than with the customary units. THINKING METRIC is the aim of all programs. In helping young learner to think about measures in metric units, it must be first recognized that the concern is teaching measurement. From this point of view it does not matter which sets of standard units are ...es matter very much that complicated conversions from one system to another are not stressed. The a s a consistent sequential program which teaches children to measure and quantify many properties of things in their environment. Further, after instruction the child should be able to share his data with other and to receive communications from others throughout the world.

Older learners, including classroom teachers do need some "rule of thumb" conversions to begin to relate to the new measures. Only few technical specialists will be required to use precise conversion factors to translate old measures new ones. The following table gives a few such values.

SOME "RULE OF THUMB" CONVERSIONS FOR ADULTS ONLY

LENGTH:
- A *millimeter* is about ...nes of a dime
- A *centimeter* is about of common paper clip.
- A *meter* is a little longer than a yard.
- A *kilometer* is about s of mile.

AREA:
- A *hectare* is about the size two football fields. (Two and a half acres)

MASS (WEIGHT):
- Five *grams* is about the weight nickel.
- A *kilogram* is a little mo than pounds.

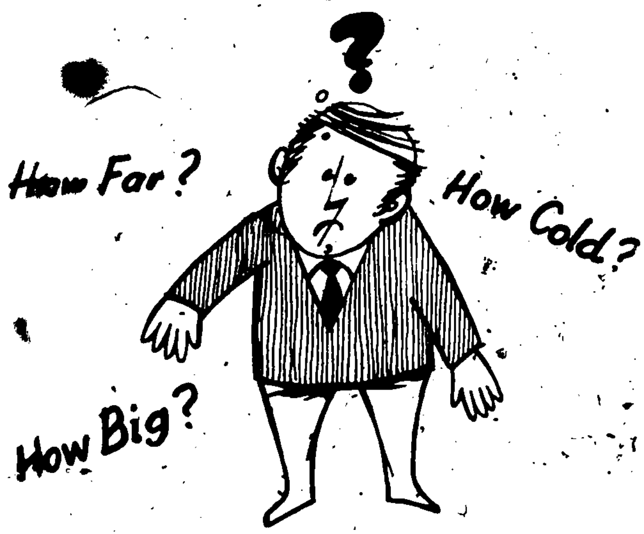
LIQUID VOLUME:
- Five *milliliters* is about one teaspoon.
- A *liter* is a little larger than a quart.

TEMPERATURE:
- To find degrees Fahrenheit, double °C add 30.
- 20 °C is comfortable in the house.
- 37 °C is body temperature.
- 100 °C is boiling point for water.
- 0 °C is freezing point for water.

A continuing goal in measurement is the ability to estimate. With the movement to metrics, the need for practice in estimation as a part of the mathematics program is intensified. Until metric measures are more a part of everyday life, students will not have the reinforcement outside the classroom that is necessary for skills in estimating.

This extra sensitivity to estimation of metric measures builds awareness of the measures. For example: suppose you wanted to learn to measure temperature in degrees Celsius. You could carry a small thermometer and measure the different temperatures encountered or you could use a conversion formula. A more effective idea might be to begin estimating as soon as possible. Ask yourself, as you move through the door, "What's the temperature in this room? Outdoors: "What's the temperature right now?" In the refirgerator? In the freezer? Out in the hall? — Then, each time, after you have estimated the temperature in degrees Celsius, check the thermometer to see how close you came. About a week of practice and verification should give you a "feel" for the Celsius readings and an ability to use its scale in estimating temperature.

In 1973 the Michigan Department of Education published the *Minimum Performance Objectives for Mathematics Education in Michigan*. The "Measurement Strand" in this publication has been revised for metric units and is available in a *Metric Appendix*. Subsequent publications of the objectives will incorporate this material. The measurement objectives are presented in groups in the metric appendix: Geometric (linear, square and cubic units) and Non-geometric (temperature, mass and liquid). Measurement objectives for angles and money were not rewritten since there will be no change required by the shift to metric.



The Michigan objectives have been reviewed and revised by groups of classroom teachers and other educators, but they originally stem from the work of the Michigan Council of Teachers of Mathematics (MCTM). This organization is a state-wide group, primarily made up of secondary and elementary teachers of mathematics. MCTM also has prepared a very useful document for elementary teachers entitled *Metric Measurement Activity Cards, Monograph #4*. The materials in this monograph can be readily reproduced for instructional use. A similar Monograph #11, *Activities for Teaching Measurement* is available for the upper grades.

The nation-wide association of mathematics educators is the National Council of Teachers of Mathematics (NCTM). Their journals, *The Arithmetic Teacher* and *The Mathematics Teacher*, are published by NCTM and both have been influential in planning for metric education. For example, a set of competency goals or objectives for metric education recently appeared in one of the journals.*

There are some differences between these two sets of goals or objectives. However, the work of NCTM and MCTM generally is consistent. Most of the differences are minor and involve only slight shifts of content between grade levels. Overall, the NCTM goals are less detailed than the MCTM objectives since they are restricted to metric measure, whereas the Michigan goals deal with measurement in general. Teachers probably will want to read both sets of goals or objectives and adjust specific ideas to their own situations.

Why is the United States changing to the Metric System? Like most big, expensive adjustments that a country makes, this change is long overdue and the result of many forces. One significant factor is economic. The United States is the last of the industrialized nations to adopt the SI units. Thus those to whom it sells and those from whom it buys all can deal with each other more easily than they can with us.

* NCTM Metric Implementation Committee, "Metric Competency Goals", *The Arithmetic Teacher*, January, 1976.

Another factor is international communication. Only a handful of smaller nations remain on other systems, and scientific and engineering standards are needed on an international base. There are, of course, many other pressures at work to move the United States to become one of the metric countries, and fortunately there are some very good things about the metric system for teachers and children.

The system has a sensible structure. The metric measures make up a logically conceived system that has been designed for computational simplicity. Measures are related through a factor of ten. Linear measure, area, volume, capacity, mass and force are all integrated. The metric system does not employ the assortment of multiples involved in the customary units. No longer will people have to remember the many multiples to relate inches, feet, yards, rods, miles, acres; Avoirdupois ounces, Troy ounces, pounds, short and long tons; not to mention liquid pints, quarts, and gallons compared with dry pints, quarts, pecks and bushels!

Metric measures will be easier to learn and to teach. Elementary students learn to count money and compare prices as an application of the decimal system, but they have had to treat other measurements as a separate topic. With the metric system in use, problems about place value, money or metrics each will reinforce skills in the other.

10 The Big Number in Metric

II.
Metric Measurement Units

One of the important considerations in the national effort to extend the use of the metric system is the need for a consistent use of terms and symbols in communication. Educators must be aware of accepted practices in the application of metric units and be alert to possible inaccuracies in the instructional materials that they plan to use. Materials have been produced and are on the market which contain errors. The metric system has evolved over the last 180 years and details of the system are discussed at regular sessions of the International Commission. The modernized system adopted in 1960 as the Systeme International or SI is the basis of current practice.

There are seven basic SI units.

SEVEN FUNDAMENTAL UNITS

To Measure:	*Name of Unit*	*SI Symbol*
Length	meter	m
Mass	kilogram	kg
Time	second	s
*Thermodynamic Temperature	kelvin	K
Electric current	ampere	A
Luminous Intensity	candela	cd
Amount of substance	mole	mol

* For everyday usage, plan to use degrees Celsius (°C), which was previously referred to as "degrees Centigrade".

Other units are derived from these seven and not even all the seven basic units will be used in everyday living. Everyday usage will include a unit of length (meter), a unit of mass (kilogram), a unit of liquid capacity (liter), a unit of temperature (degree Celsius), and a unit of time (second). Several of these units do not appear in the list of basic units; they are derived from the basic SI units. The liter measure is defined in terms of the meter and the Celsius scale is derived from the Kelvin scale.

Another important aspect of SI is the establishment of agreed upon prefixes and symbols. Each measurement has one unit associated with it and larger and smaller quantities are measured in a power of ten times that unit.

e.g. It would not be appropriate to measure the distance from Marquette to Detroit in meters. Therefore, it is measured in thousands of meters or kilometers.

Neither would it be appropriate to measure the length of a person's nose in meters. It would, however, be appropriate to measure the length of a nose in hundredths of a meter or in centimeters.

Two prefixes, kilo (1 000 times) and centi (0.01 times) have been used.

More prefixes have been defined than will be in general use. Children should not be required to learn those prefixes which will not be in general usage. A partial list of prefixes is given below with those used most frequently in italics.

SI UNIT PREFIXES

Prefix	*Symbol*	*Factor*	*Meaning*
mega-	M	1 000 000	one million times a —
kilo-	k	1 000	one thousand times a —
hecto-	h	100	one hundred times a —
deka-	da	10	ten times a —
meter liter gram		1	(base unit)
deci-	d	0.1	one tenth of a —
centi-	c	0.01	one hundredth of a —
milli-	m	0.001	one thousandth of a —
micro-	μ	0.000 001	one millionth of a —

The prefixes that will have major use have been familiar in words such as these:

kilo- kilowatt
centi- centipede
milli- millipede

More complete descriptions of SI terminology are available. The American National Metric Council, the American National Standards Institute and our National Bureau of Standards have provided technical publications that contain more complete listings of terminology and describes their proper use.

The following three publications currently are available:

ISO Recommendation R1000, Rules for the Use of Units of the International System of Units, 21 pp.
American National Standards Institute
1430 Broadway, New York, NY 10018

ANMC Metric Editorial Guide — Interim Guide to Accepted Metric Practice, 11pp.
American National Metric Council
1625 Massachusetts Av. N.W. Washington, D.C. 20036

NBS Guidelines for Use of the Metric System, Nov., 1974
Metric Information Office, National Bureau of Standards
Washington, D.C. 20234

III.
SI Do's and Don'ts

1. Use a space to group digits on either side of the decimal point.
   EXAMPLE: 2 600 000.0 NOT 2,600,000.0
   3.141 592 NOT 3.141592

2. Follow unit symbol with a period only if it ends a sentence.
   EXAMPLE: 500 m long. NOT 500 m. long.

3. The same symbol is used for singular or plural.
   EXAMPLE: 3 kg or 500 km NOT 3 kgs, 500 kms

4. Values less than 1 are in decimal form, not fractional, use a zero before the decimal point.
   EXAMPLE: *0.25 ml** NOT ¼ *ml*, .25 *ml*

5. Use a space between the numeral and symbol.
   EXAMPLE: 20 mm, 3 °C NOT 20mm, 3° C

6. Do not use a prefix as a word.
   EXAMPLE: A kilogram of flour. NOT A kilo of flour.

7. Exponents ² and ³ are used with symbols to indicate square or cubic measures.
   EXAMPLE: 5 square meters: 5 m^2 NOT 5 sq. m.
   2 cubic centimeters: 2 cm^3 NOT 2 cc

8. Avoid mixing units.
   EXAMPLE: 1.34 m NOT 1 m 34 cm
   100 cm by 20 cm NOT 1 m by 20 cm

9. Unit *names* are treated as common nouns. (Exception: Celsius is capitalized).
   EXAMPLE: kelvin, ohm, newton

10. *Symbols* derived from proper names are written with the first letter in upper-case.
    EXAMPLE: kelvin: K
    newton: N
    degrees Celsius: °C

11. Use a product dot to indicate compound units formed by multiplication.
    EXAMPLE: A moment of force is measured by a newton meter: N · m. NOT Nm

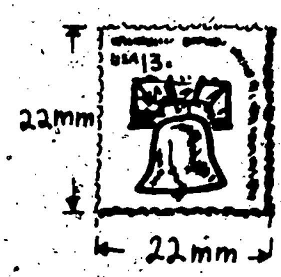
12. Units derived by division are indicated by a slash, or by a product dot and a negative exponent.
    EXAMPLE: m/s or m · s^{-1}

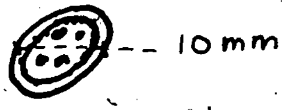
* The December 10, 1976 Federal Register. Vol. 41. No. 239 contains a recommendation that "L" be used as the symbol for liter.

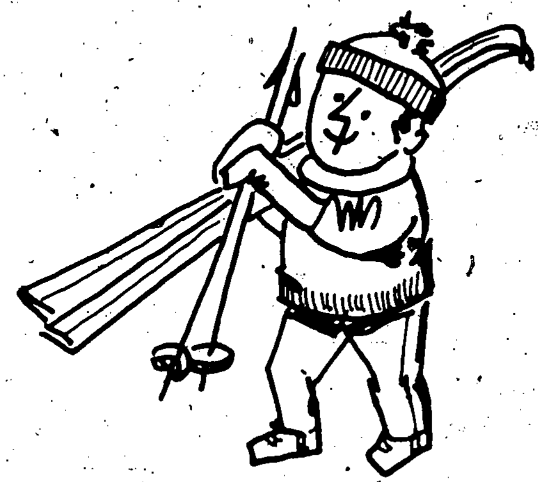
Length

Distances between towns are measured in kilometers

kilometer	1 km=1000 m
meter	100 cm
centimeter	10 mm
millimeter	1 mm



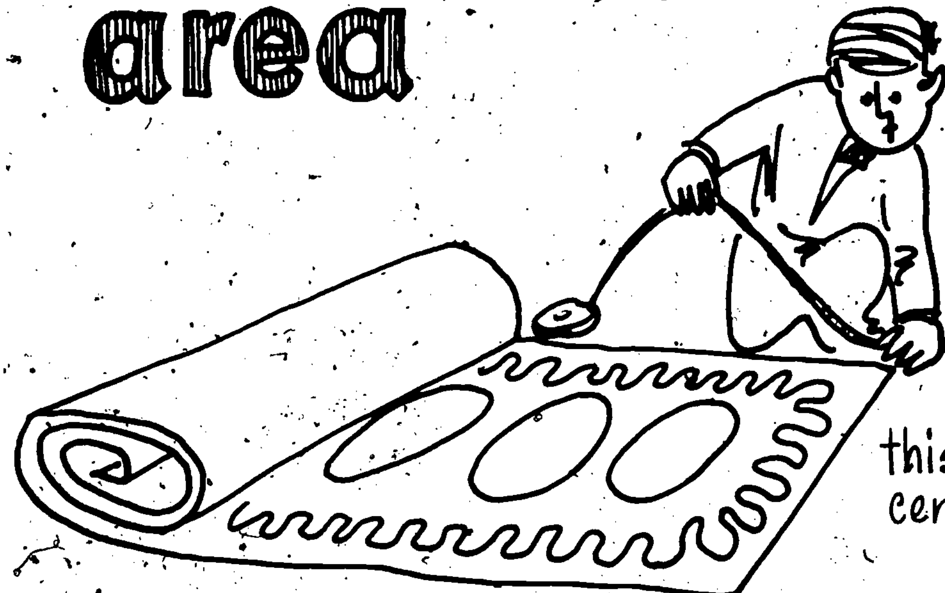




-small objects are measured in millimeters-mm.

-skis are measured in centimeters-cm.

area



$= \underline{cm^2}$

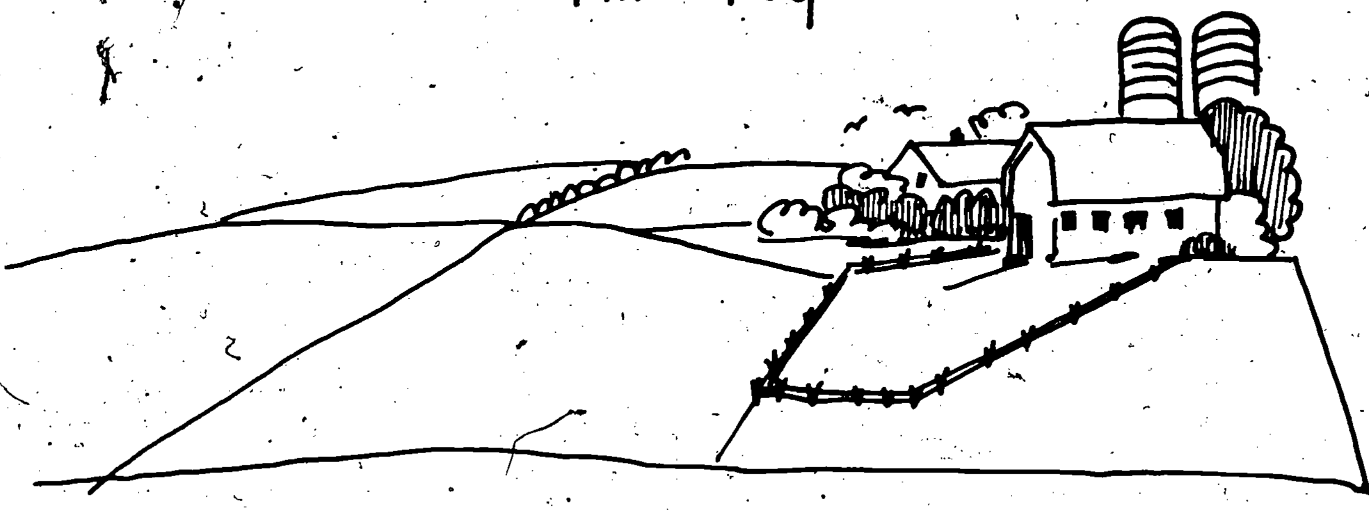
this is a square centimeter

Carpet is sold by the m^2

$0.001\ ha = 1\ m^2$ $\qquad$ $10\,000\ m^2 = 1\ ha$

$10\,000\ cm^2 = 1\ m^2$ $\qquad$ $0.000\,1\ m^2 = cm^2$

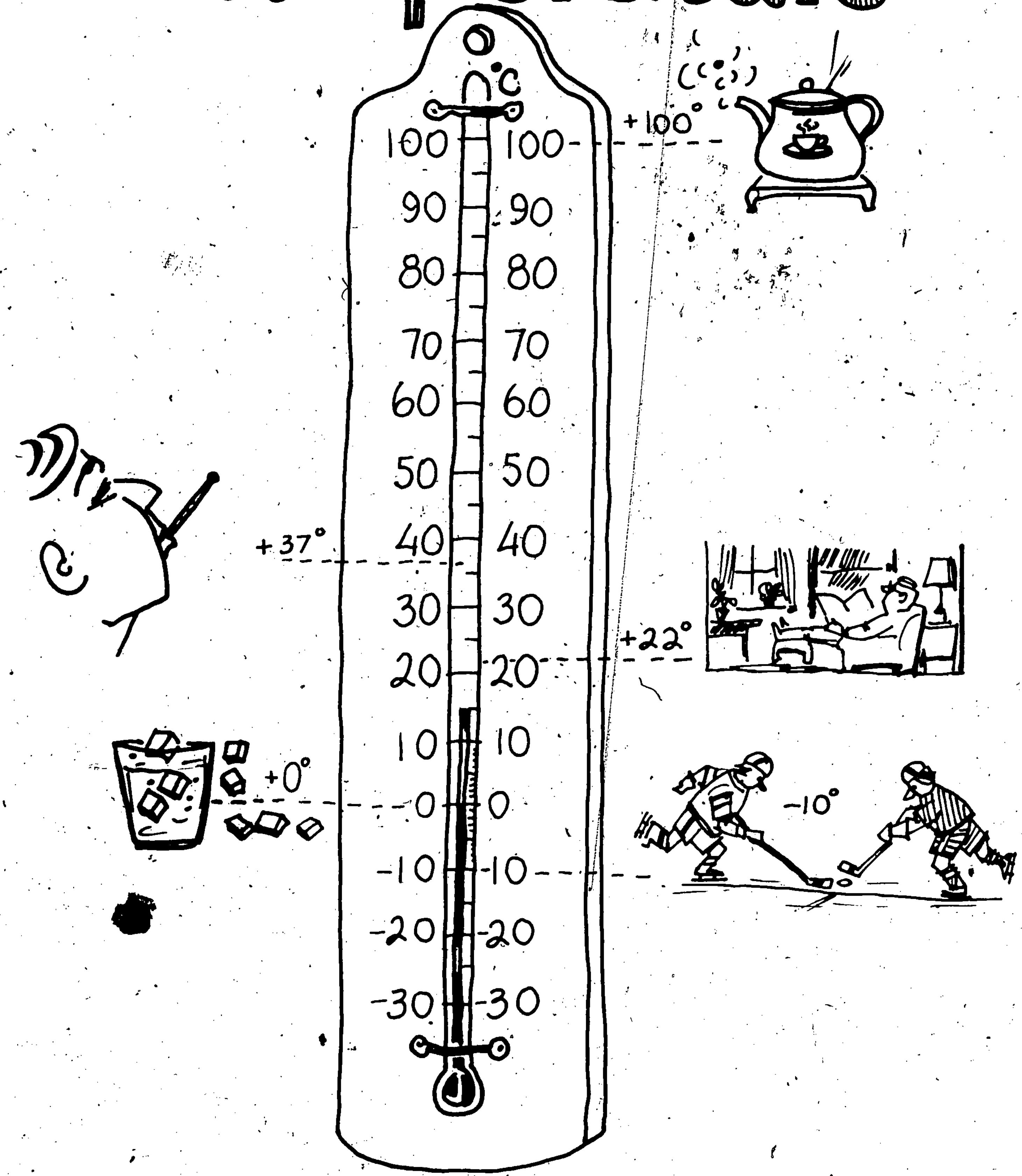
$1\ m^2 = 1$ square meter



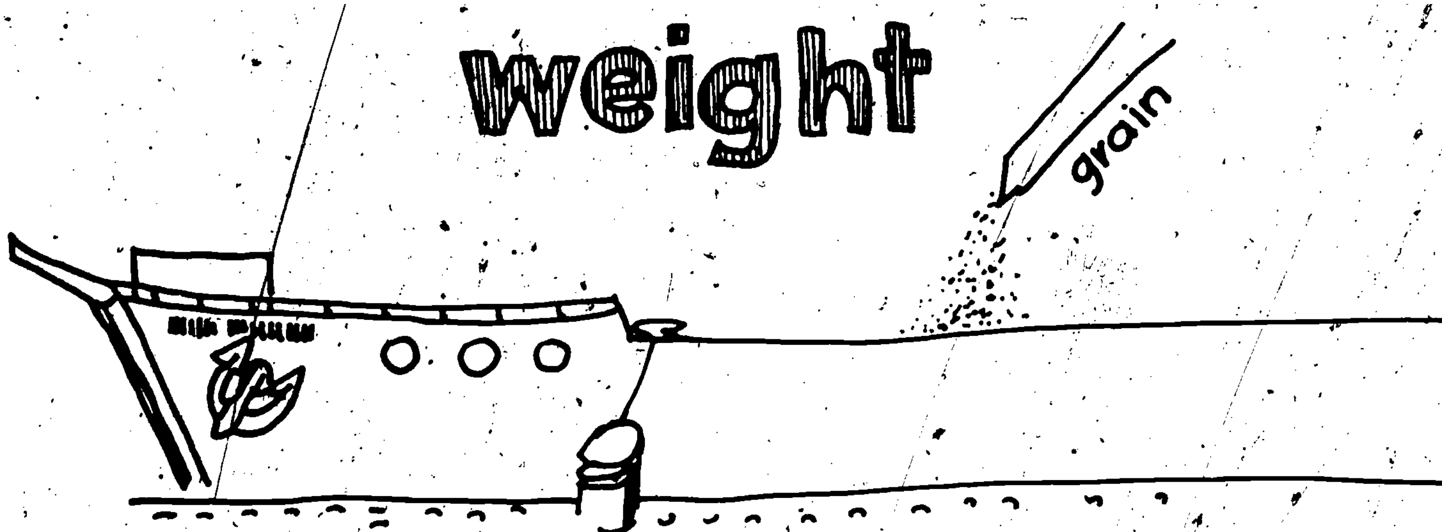
1 ha (hectare) is a little smaller than 2 football fields

Land is measured in hectares.

temperature

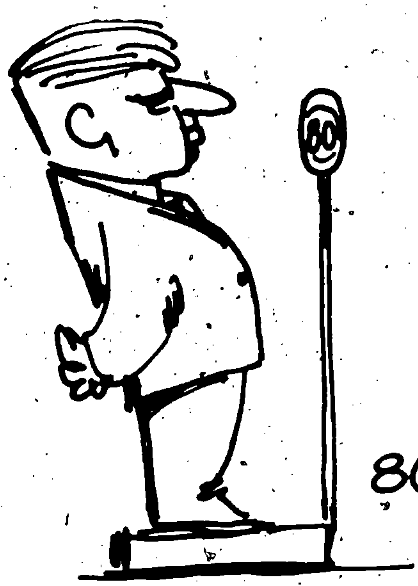


weight

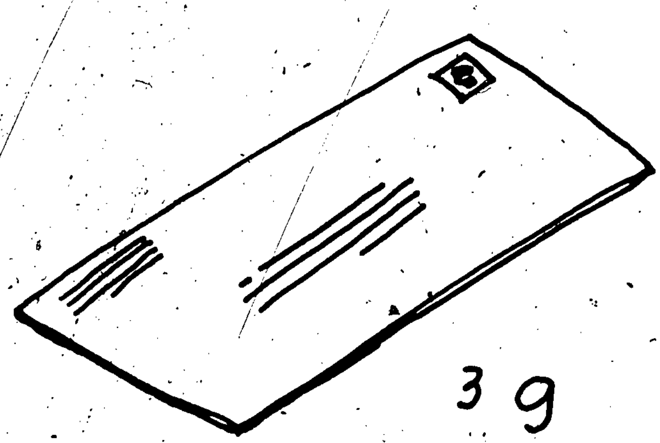


Ship loads of grain are measured in metric tons (t)

metric ton	(t)	1 t = 1 000 kg
kilogram	(kg)	1 kg = 1000 g
gram	(g)	

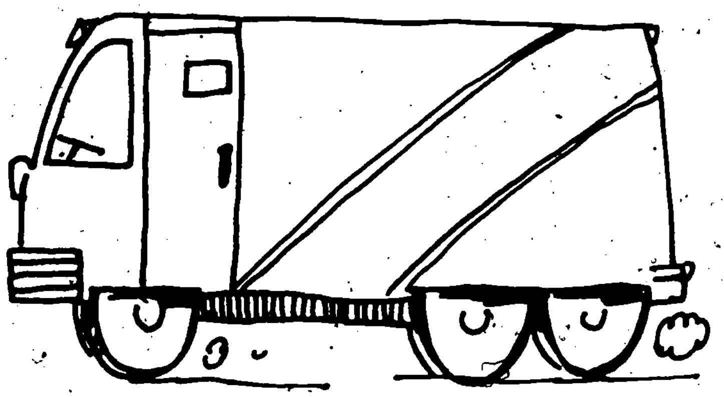


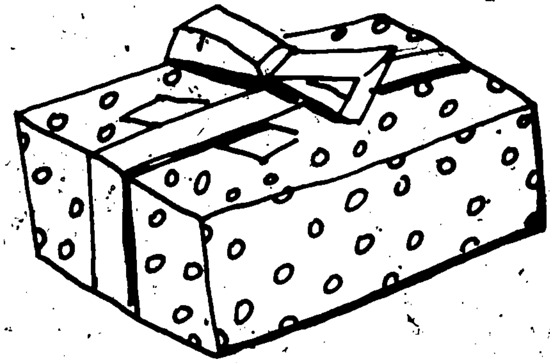
a person's weight is measured in kilograms



a letter is weighed in grams

volume



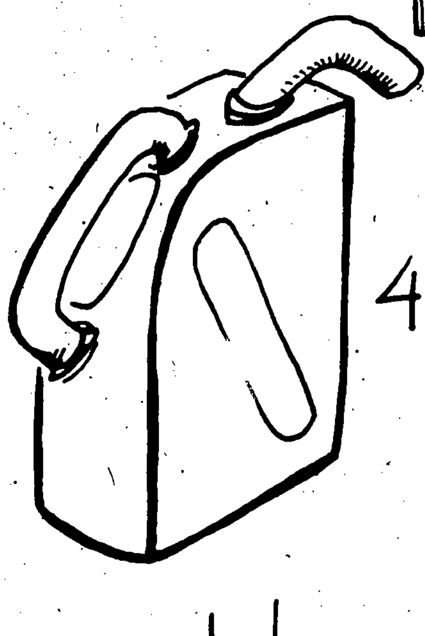


measure truck capacity in-$\underline{m}^3$

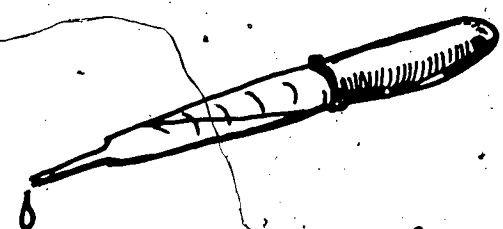
how many-$\underline{cm}^3$?

cubic meter . . . . m^3
cubic centimeter $1\,000\,000\ cm^3 = 1 m^3$

liquid capacity



4 l



0.05 ml

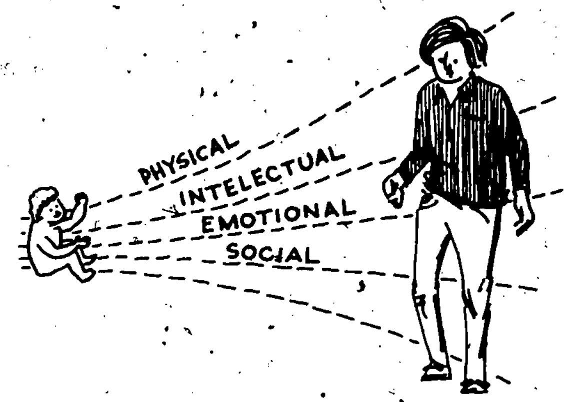
liter (l) l
milliliter 1 000 ml = 1 l

V.
Child Development and Learning to Measure

Measurement is a *learned process*. This statement has definite implications for your instructional program in metric measurement. The fact that measuring is a process says that measuring is dynamic, not static; that a child does not learn to measure by looking at a picture of a paper clip lying beside a ruler. Rather, the child learns to measure when he/she handles the ruler and the paper clip and learns to place one end of the clip at zero, notes the mark on the measuring stick closest to the point where the other end lies, and learns what value to attach to that mark. This *process* is one of the necessary learning experiences and processes are internalized by *doing*.

An individual develops physically along a continuum from random movement to highly coordinated object manipulation. A child first learns to control overall body movements. Once the body movements are coordinated, the child learns to coordinate object control with body movement. Along with physical development there is evidence to show that an individual develops along an intellectual continuum that has thinking in simple, concrete terms at one end and complex reasoning in abstract terms at the other. The child first learns intellectually to manipulate objects. Once able to process information about objects, the learner may process information presented pictorially and then symbolically. The intellectual processes used to process information also extends in a range from knowing to judging.

An individual also develops emotionally along a continuum. The emotional continuum includes being aware of one's own feelings at one end and developing a consistent value system at the other. A social development continuum parallels the emotional one. The child moves along the social and emotional continua from an awareness of the feelings of others to consistent and effective functioning as a group member.



Development Continuum

What implications do these developmental sequences have for instructional planning? In general, the instructional sequence for metric measurement must be in harmony with the student's developmental needs. Her/his intellectual needs describe a curriculum that begins with perceptual observations and the manipulation of real objects, proceeds with estimations and counting activities, again, with real materials, and finally deals with numerical and other symbolic representations and the use of measuring instruments. The activities which are selected to implement this curriculum sequence should reflect the social and emotional development of the child. Early activities involving individual manipulation and exploration of properties should be provided as well as opportunities for children to share their findings with others. Formal group projects involving cooperative effort or a division of labor should be introduced later.

The developmental model provides guidelines for the needed curriculum for measurement education. A second kind of analysis originates within the content itself. What does it mean "to measure" and what kind of an instructional sequence does this imply?

In the simplest form, measurement is the comparison of some characteristic of an object to a referent: "As tall as the house." "As long as my arm." The development of this concept proceeds from concrete perceptual comparisons to more abstract numerical representations. The beginning learner must first be able to differentiate among the many characteristics of an object and to focus upon one in particular before any comparisons can be made. In measurement, we are interested in characteristics such as length, area, volume, mass (weight), time, temperature, force, speed (velocity) and angle. Other characteristics with which young children deal are shape, color, brightness, texture and the pitch of sounds, but these are not usually carried beyond perceptual comparisons until much later.

A content analysis of measurement has been done by Gagné and is incorporated into the *Science . . . A Process Approach*** materials. Behavioral objectives were prepared and sequenced with learning activities for this program and metric measurement was one of the process skills selected. A more recent analytical method developed by Edward Smith has also produced a detailed sequence applicable to learning metric measure. (See appendix C). Smith views measurement activities as examples of the more pervasive quantification concept in science and mathematics, that is, the assignment of values to properties following particular rules or procedures.

Following Smith, one can describe tasks or actions which enable the learner to effectively carry out a measurement. These activities, in turn, can be arranged in a developmental sequence for instruction (See Table 1) and research on the sequence and the lessons themselves can be done to ascertain the usefulness of each lesson and the appropriateness of the order. The sequence further provides a guide for constructing objectives, evaluation items, and a variety of instructional activities.

The sequence given in Table 1 is applicable to any additive measure including length, area, volume, and mass (weight). Temperature requires a modified sequence since this property does not simply sum when materials are combined.

Few measurements can be carried through the entire sequence in any one grade level. The development of the concepts underlying the tasks may take longer than a school year. The teaching of measure is further complicated when one remembers that each child is at a unique place in her/his physical, social and emotional development. There is however, a gradual change from very concrete comparisons to more abstract representations as we deal with older learners. It is not that real objects and measures can ever be eliminated, but for the more mature learner, her/his previous experiences allow less time to be given to the early activities.

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* See also Osborne, Alan R. "Metrication, Measure and Mathematics" in *A Metric Handbook For Teachers*. National Council of Teachers of Mathematics, 1974.
** *Science . . . A Process Approach.* Xerox

TABLE I
A LEARNING SEQUENCE FOR MEASUREMENT

A. *Perceptual Observations:*

Using estimation and direct comparisons of physical properties (length, area, volume, liquid measure, mass (weight), force, time, angle).

1. Determine whether two measures are the same or different.
2. Select two objects with the same or different measure from a set.
3. Identify which of two objects has the greater measure.
4. Select the object with the greatest measure from a set.
5. Order a set of objects according to a given measure.
6. Describe an object in terms of another on a given measure.
7. Match a set of objects to a larger measure.

B. *Numerical Measurements With Unit Objects:*

Using estimation and by counting the number of smaller objects equivalent to a larger one.

8. Compare body units (head, thumb width, foot) to a given measure.
9. Compare sets of non-standard units to a given measure.
10. Compare sets of arbitrary units to a given measure.
11. Compare combined sets of arbitrary units to a given measure.
12. Compare sets of standard units to a given measure.
13. Select an appropriate unit for a given measuring problem.

C. *Numerical Measurements With Instruments:*

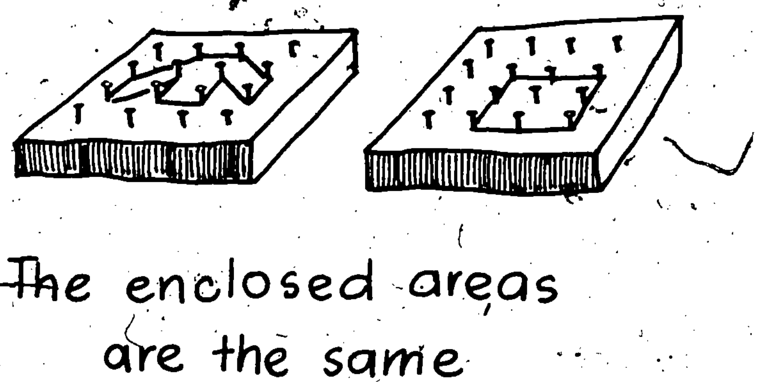
Using estimation and appropriate instruments.

14. Calibrate an instrument to represent a set of objects.
15. Calibrate an instrument using standard units.
16. Use an instrument to determine a measurement.
17. Select an appropriate instrument for a given measurement problem.
18. Give an operational definition for measuring an object.

Perceptual Observations

The purpose of these first direct comparisons is to provide an experiential basis for a meaningful introduction to numerical values later. The tasks include working with sets of objects as well as simple comparison of one object to a referent. The selection of an extreme value from a set (Task 4) is one means or strategy for learning to arrange objects in a series. There are other seriation procedures, but the scheme of first finding the largest (or smallest), and after setting it aside, again selecting the largest in the set is an easily learned strategy.

Verbal description is included by introducing comparitive terms (Task 3) and by asking for an operational definition. Operational definitions define words in terms of something that must be done rather than merely in terms of other words. Inclusion of such an activity at this point facilitates a commonly understood meaning of "measure", helps the learner realize the need for standardization and reinforces the procedures for measuring previously learned.



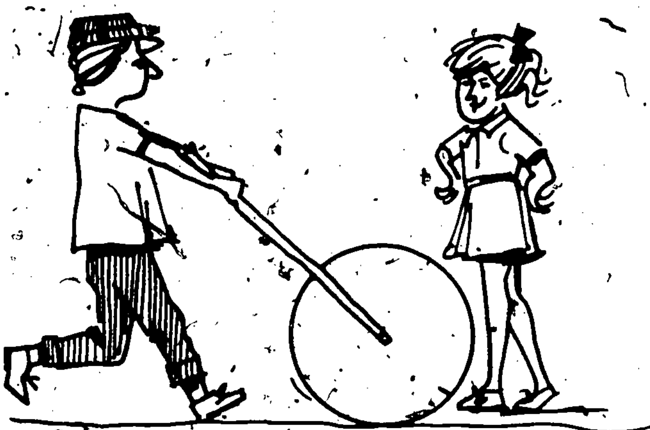
Numerical Measurement

Estimation can begin with direct comparisons, though until the child is capable of conserving length as well as other measures, the actual placement of objects next to each other is necessary to determine which has more or if they are the same. As soon as the matching of a group of smaller objects to a larger one can be performed, counting and estimating the count should begin. Estimation is important in learning to measure, as noted earlier, since it helps the learner to relate perceptual and numerical measures and to gain a "feel" for the size of the value assigned to an object on some measure. Estimation practice also helps the learner avoid big errors not only in measurement, but in subsequent calculation problems.

Body units, non-standard units, arbitrary units and finally standard metric units are used to measure objects. The interrelationships among metric units can be illustrated as a comparison of a set of standard units to a larger unit. For example, ten centicubes are as long as a one decimeter rod. An opportunity to use combined sets of objects of different sizes to equal a longer object is also important in learning more about numbers and sums and Cuesinaire rods are useful for this activity. The last task in this group is a practical skill that represents the arbitrary decision about which unit fits a given situation. Any volume, for example, could be measured in cubic meters, however it is more practical at times to use cubic centimeters or liters or some other units.

Numerical Measurements With Instruments

The final section of th sequence leads the learner through activities which culminate in the use of an instrument such as a ruler length, a graduated container for liquid, a thermometer for temperature or a scale for weight. The first activities in this section may be unfamiliar in that they empha- the calibration or creation of an instrument from sample of real measurements. This appro designed to give experiential support to the as he/she later applies an actual instru measuring activities. Though instruments made for arbitrary units, it may only be nec to use standard units to maximize tran ordinary instruments.

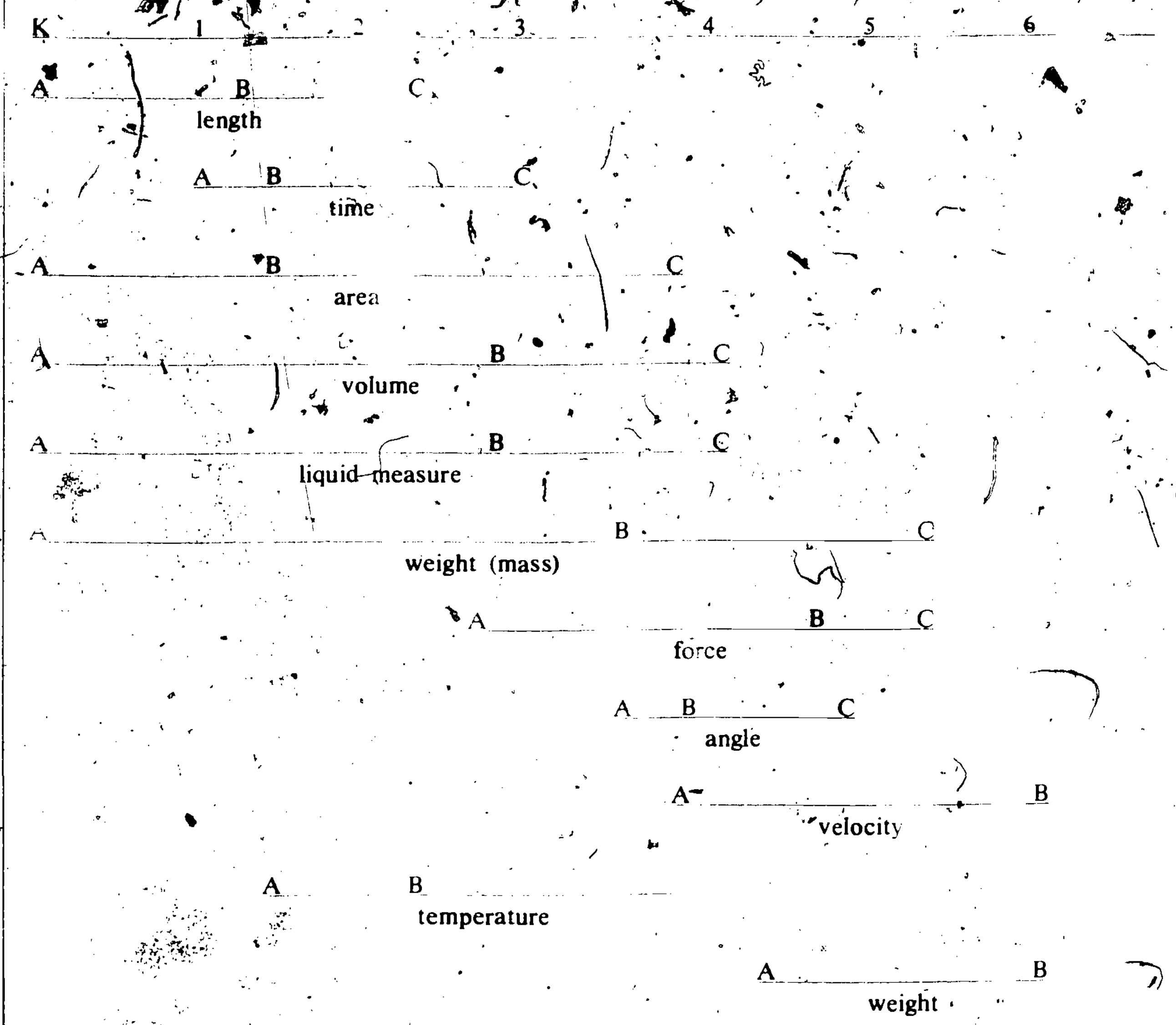


Perhaps the most striking idea about the use of instruments is that the learner needs many experiences prior to using them. When the learner can make comparisons, estimate equivalence in some standard unit, relate an abstract number of units to a measure, and translate this number to a mark on a scale, then he/she can begin to apply instruments to her/his measuring tasks.

Some Do's and Don'ts for Teaching

1. Do provide for a w... range of activities in the classroom including: different measures and different levels from concrete to abstract.
2. Don't introduce small units (millimeters, milligrams) before the child can perceive or relate these units to others.
3. Do provide instruments calibrated in units the child can relate to real measures and that can be manipulated physically by the child.
4. Don't provide all practice measuring with pictures of objects and then expect the child to measure real things successfully. Conversely don't use only paper and pencil measuring tasks and pictures when testing.
5. Do become genuinely familiar with SI yourself, so you can estimate measures and discuss them conversationally. In other words, practice THINKING METRIC.
6. Don't worry about conversions, if the learner can really measure he can adapt to different units without much difficulty.
7. Do relate metric units, money and the decimal system in social studies, history, language arts, art, physical education, music and other areas, as well as in mathematics and science lessons.

TABLE II
A CURRICULUM PLAN FOR MEASUREMENT



= Perceptual Observations
= Numerical Measurements with Unit Objects
Numerical Measurements with Instruments

Table II shows a rough curriculum plan for measurement arranged according to the different types of measures and grade levels. Perhaps the most important idea apparent in this table is that the learning sequence is essentially the same for all of the different measures. Whether we are dealing with a first grader's introduction to Time or a third grader's introduction to Force, the series of experiences remains the same. Even for an adult learner, we need to begin with observations, move to numbering and finally learn to use instruments.

Teachers of children in grades K-3 will be dealing with the most complex situations in teaching measurement. Not only are they likely to be involved with several types of measures (length, area, volume, liquid measure, temperature, time and weight) they also will find children at different places on each measure. Good objectives or performance criteria and individual records will be most helpful to the teacher in planning activities. The range and variety of laboratory materials available in the classroom is also important. Durable, attractive, manipulatives covering many measurement activities should be easily accessible for the child to explore. Lessons which include measurement should be frequently included in areas outside of science and mathematics. Art, history, social studies, language arts, physical education, outdoor programs, and other subjects can provide useful applications of measurement. Of course, most science lessons include or are based on measures and quantitative observations. The intimate relationships between our grasp of real numbers, rational numbers, finite sets, mapping and other concepts and our understanding of simple measurement processes brings mathematics into the curriculum design.

Classroom Activities by Grade Levels

Kindergarten

Comparisons without units are the earliest measurement activities. Taller-shorter, heavier-lighter, holds more-holds less, are more specific than bigger-smaller. The selection of an extreme value should follow next, tallest, shortest, holds most, etc. This type of comparison is important to the instructional strategy for acquiring the ability to seriate. Rather than randomly selecting pairs to measure, the child can select the longest, for example, and then repeat the same search for the (next longest. This procedure or strategy depends on the child's development of conservation of length for success.

Specific topics can include length, area, volume, mass (weight) and liquid measure comparisons. Blocks, dowels, cut-out shapes of various sizes, containers and pourable materials, along with the space to work or play with the materials, are important. Plain, rather than colored, objects make such comparisons simpler. Objects of several sizes but the same color permit single property comparisons.

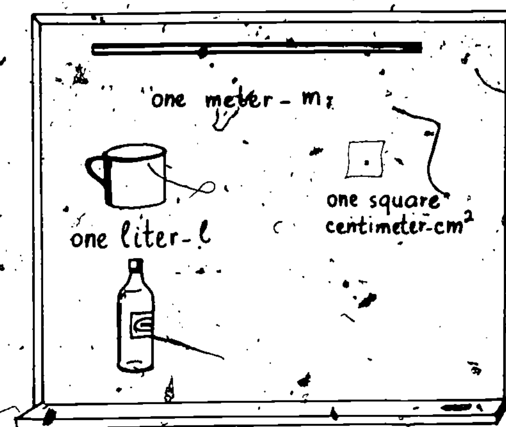
First Grade

The use of reference objects and verbal statements about activities can begin along with other first grade units. In fact, these ideas fit nicely with early work in reading. Counting activities are usually underway and the idea of numerical measurement with unit objects is appropriate. Naming units and associations beween units presented in concrete forms are meaningful. Making personal measures are important to the child. Height, weight charts of these statistics and of the outside temperature in degrees Celsius are activities which students enjoy discussing and doing. Materials should be in the room throughout the major part of the school year so that students recognize a liter, a meter, a kilogram, and, perhaps, a decimeter and centimeter as well.

Major attention in the first grade measurement curriculum is given to activities which enable the students to perform activities matching lengths and to have preparatory work for these activities with volume and area. Sets of small objects along with things to measure need to be available. (Paper clips, toothpicks, tongue depressors, rods, cubes, dowels, cardboard squares, paper tape, large containers and pourable materials are among the many useful materials for activities).

Second Grade

Instruments for measuring length, using numerical measures for area, weight and liquid measure; the relationship of our monetary system to metric units; and the use of more arbitrary units may be introduced in second grade.



Particular attention should be given to the ability of children to conserve weight and liquid volume since this will affect their performance on these activities. Some children may just be ready for the conservation of length and they will need to work with seriation and counting activities before beginning to work with rulers. (See first grade).

The amount of practice activities needed to work with calibrated rulers will vary from learner to learner. It is helpful if the first rulers are not marked off in millimeters. Rulers with decimeters only or with cenimeters only are preferred. These can be made in the classroom. At this early level educators should try to be consistent with measurements and give the reading to the *nearest whole unit*. Because the metric system is based on ten we can spend less time on halves, quarters, eighths and sixteenths that were important to the customary units.

The idea of equivalence among different sets of units including arbitrary and standard units should again be emphasized. Since area measure will probably be new to all the children, covering a given area with different sets of objects may be a good activity here. For the more advanced learner the shift to grid paper and transparent grids for counting area can begin. A related activity in volume measure is the construction of a solid figure from unit objects which matches a given solid. The abstraction of a picture of the solid to be built may also be tried.

Third Grade

The new variables which occupy this grade level are weight (mass) and temperature. A good deal of consolidation of previous work on length, time and area will also take place and since most children will recognize the conservation of matter, the equivalence of solids, liquid containers or areas of unlike shapes can be studied. Students can determine how many small containers of liquid it takes to fill a large one and how many small ones can be filled from a large one,

Longer range experiments involving measurements can be carried out by the learners to gain needed practice with rulers, meter sticks, tape measures, centimeter grids. Mapping the playground and making scale drawings of their room are examples of activities involving many measurements.

Reading a thermometer and measuring temperatures indoors, outdoors, in water filled with ice cubes, and at intervals as the ice cubes melt, in the soil and at different places and heights in the classroom are activities that can be recorded and discussed in relation to studies of environment, geography, health, and science.

At this level students become familiar with metric standards through using them and can identify models of the liter, the centimeter, decimeter, meter and recognize whether a mass will be described in grams or kilograms. By using pan balances to compare objects with model gram and kilogram masses, students can begin to describe mass (weight) numerically.

Time measure with water clocks, a candle, or a pendulum offer numerical measures of change and can parallel telling time from ordinary clocks.

Fourth Grade

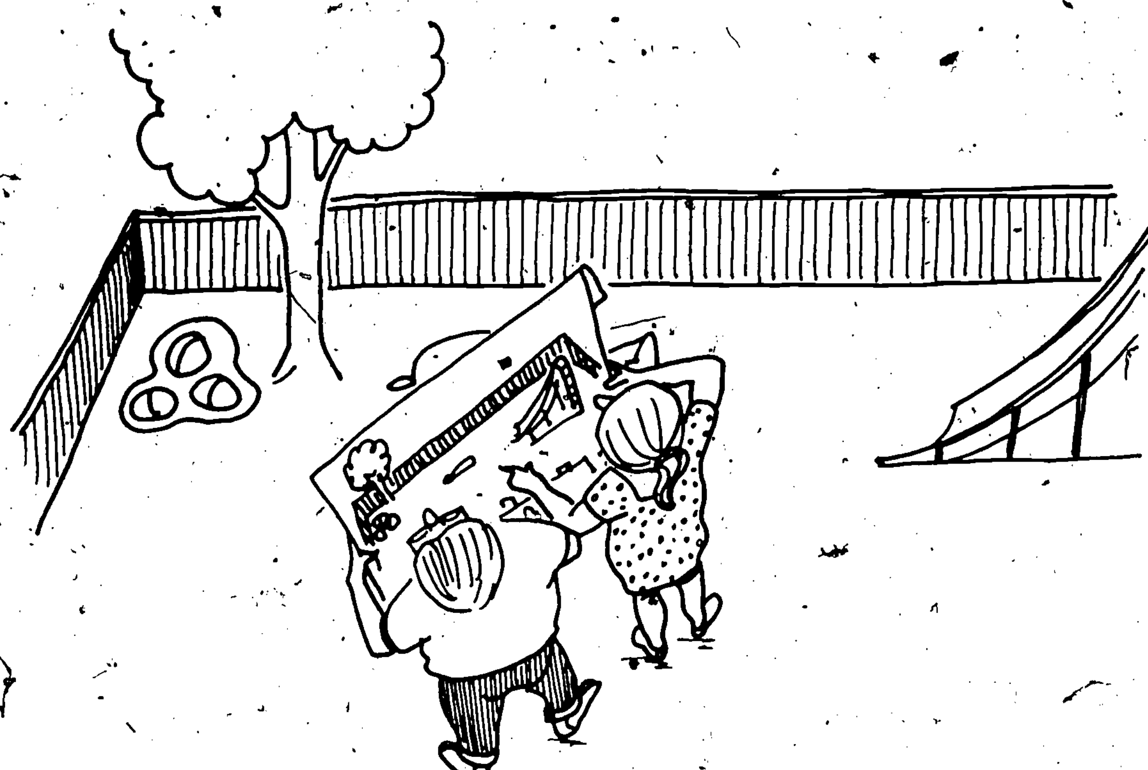
New measures that may be considered in the fourth grade are those of force and of angle. Activities related to mass, temperature and volume should be continued and advanced upon the basis of work in previous grades.

The use of linear units should include those from the millimeter to the kilometer. Activities with the milligram should be added to those with the gram and kilogram; and the milliliter as well as the liter. Applications of measurement in the community, in commerce, industry, science and the arts should be introduced. Discussions and reports about the development of the metric system and its international usage are meaningful at this level.

Activities which lead to the measurement of force can begin with a string, a rubber band, a small bag, and a few marbles to put in the bag when it has been tied to the rubber band. Compare the lengths of the rubber band as you add marbles to the bag dangling at the end of the string. Decide how these changing lengths could be measured, and you have provided some background for investigating other forces; whether pushes, pulls, or earth-pull measured by the change in springs or rubber bands.

Angle measurement can involve the playground slide, a nearby hill, shadows of a stick or pole outdoors, mirrors, placement of a ladder and similar familiar objects.

To work with greater quantities will require students to have experiences in measuring outside the classroom. Estimating distances in the 5 to 10 meter range can be done outside as well as foot races and throwing or punting contests with metric tape measurements to determine the winners. Longer distances such as a kilometer, five or ten kilometers can involve bicycles, cars and busses. One ingenious school has already put kilometer markers along its bus routes. Dual highway signs are appearing on our highways. These out-of-door activities can be supplemented with maps, county maps of the immediate area and state maps, and scale drawings of the playground area.



Estimating and measuring volumes of packing boxes, wagons, rooms, the inside of a station wagon and the first snowfall of any depth can follow the construction of a cubic meter with twelve sticks each one meter in length.

Students of fourth grade will have had enough experiences in measuring objects of various sizes to appreciate the internal relationships among the units in the metric system. Because the system parallels their lessons in place value in our decimal system of numerals these relationships are most important.

SOME BASIC RELATIONSHIPS IN METRIC UNITS

Linear			
10 mm = 1 cm			
10 cm = 1 dm	100 mm = 1 dm		
10 dm = 1 m	100 cm = 1 m	1 000 mm = 1 m	
1 000 m = 1 km			
Volume			
1 000 m *l* = 1 *l*			
Mass			
1 000 mg = 1 g			
1 000 g = 1 kg			

Fifth Grade

This is the year of the decimal and the first intensive use of *computations* with metric measurements. Two different but related ideas are involved: a measure multiplied or divided by a whole number, and, the sum or difference of a set of measures. Expressing the result in a meaningful unit is a third skill.

Examples: (1) A rope 40 m long was used to mark off the edges of a space in the yard to be used as a garden. If the space was square, how long was each edge?

(2) *What's Your Class Mass?*
Each student weighs in on a kilogram scale and writes her/his mass (weight) on a slip of paper. All entries are totalled and posted with the date. (You may want to compare this total with a new one in two months — or after a class picnic.)

(3) What would be the mass of our school's total student "body"? Should the total be expressed in grams? Kilograms? Metric tons?

Activities involving measurement in and out of the classroom will lead to square and cubic measures and the notations involving exponents. Though the words are replaced by the symbols, the measures are read in the same manner: cm^2 - square centimeter(s); m^2 - square meter(s); cm^3 - cubic centimeter(s).

Example: Collect enough measurements of yourself, use meter-wide wrapping paper and draw a full-length portrait of yourself, complete it in living color. When cut out and palced at the artists' desks or along one wall, a class portrait results. By using a transparent grid of square centimeters, body area can be determined, volume can be estimated and a comparison with mass made.

The construction of models — boats, cars, animals, etc. — as solid figures involves measuring, estimating, proportion, area and related calculations.

Sixth Grade

With the background of experiences in measurement outlined for the previous grades, students will be prepared for work involving abstractions that are related to measurements: Greater use of estimation; graphs and tables that report recorded measures and graphs that portray related variables; applications involving two measures such as speed or velocity, and density.

Examples: Apollo X traveled at 39 897 km/h or 11.08 km/s. Determine an 11 km distance on the map of our state to visualize the ground that would be passed over in a second at this rate. Trace the path that would be made in a minute.

Water has a density of about 1 000 kg/m^3. How could you express the density of water in terms of a cubic decimeter? Check this computation against tap water weighed in your classroom. What does one liter of tap water weigh? What would the water weigh if you filled a vat that was one cubic meter in size?

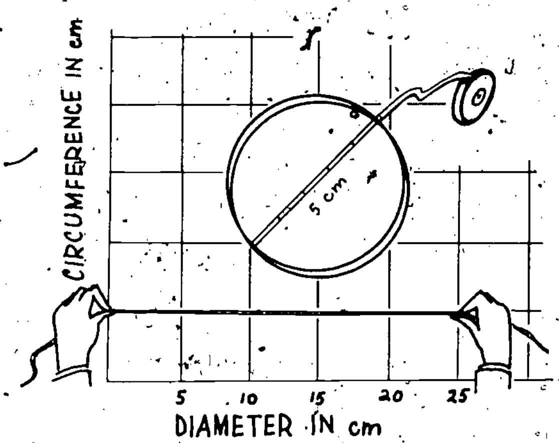
Students are curious about names for greater and greater quantities as well as those that are microscopically small. Introducing the prefixes mega-, giga-, tera-, micro-, nano-, and pico- can involve work with decimals, reading numerals, place value and an appreciation for the use of scientific notation. (30,000 = 3×10^4 etc.)

With the introduction of applications and increased familiarity with calibration, students will be ready to be introduced to additional instruments and their special uses: micrometers, calipers, bow calipers, depth gauges, clinometers, protractors and range finders. Demonstrations by people of the community who actually use them is an added motivator.

Transforming actual measurements to a drawing via scale and reading a scale drawing as well as explaining it are other aspects of abstract activities for students. Formulas for area and volume should be more meaningful following activities with the concrete — including those that involve the circle and π.

Example: Measure and record the circumference of several circular disks (5 cm, 10 cm, 15 cm, 20 cm, 25 cm in diameter).

This can be done by placing a string around the disk and then measuring the length of the string used with your meter stick. Now construct a graph of your findings. Label the y-axis CIRCUMFERENCE, the x-axis DIAMETER. Is the resulting graph a straight line? Divide the the circumference by the diameter for each point plotted. What is the quotient in each case? How do the quotients compare with the value that you have learned for π?



VI.
Choosing Instructional Material and Equipment

Measurement is best taught by measuring. Metric measurement is best taught by measuring in SI units. This is an active, "hands on" approach to learning. Instructional resources are valuable assets to the instructor.

BEWARE: The market is being deluged with materials and equipment. There are many excellent materials. However, some are better than others and only the very best should be selected for purchase as they will be used for many, many years. Prior to purchasing materials review them critically. Concern for good metric usage is utmost when anyone reviews materials that students and teachers will be using in the classroom. Considerations should be given (a) to the physical characteristics of the measuring devices to be used, (clarity, resilience, accuracy); (b) to the appropriateness of written explanations and exercises; (c) to the precision of diagrams. Here is a check list for measuring the value of instructional materials and programs. An equipment check list is included on page 23.

Materials and Programs Check List

YES?

______ 1. The materials use standard SI units in a consistent manner. (See Tables on previous pages).

______ 2. Metrication is integrated into lessons throughout the curriculum and not presented as an isolated topic or limited to a single discipline.

______ 3. Metric measures are made basic to all measurement activities. Conversion is de-emphasized in later grades and non-existent in early grades. Where conversion is necessary, it is dealt with from a metric basis.

______ 4. Measurement activities follow a developmental sequence which reflects a genuine concern for how and when children learn to measure.
(See the continuum on page 16)

______ 5. The development of the concept of measurement is included in the suggested classroom tools and written materials.

a. Non-numerical matching and comparison
b. Ordering
c. Appropriate language
d. Estimation
e. Numerical relations and mapping
f. Pictorial representation — use of scale drawings
g. Calibration and use of instruments

Books in the following list are given as examples of materials which meet the criteria for selection. They should serve as guides of what to look for.

1. *A Metric Handbook for Teachers*, Yack, et. al., Wayne-Westland Community Schools, 646 N. Wayne Rd., Westland, MI 48185.
2. *Activities for Metric Measurement*, MCTM Guidelines Committee for Quality Education, Monograph 11. H.L. Mourer, 2165 E. Maple Rd., Birmingham, MI 48008. Ready September, 1976.
3. *Activities for Teaching the Metric System*, Vol. 1, 2, Rita Brey, 18750 Five Points, Detroit, MI 48240, 1976, $3.75 ea.
4. *Activities Handbook for Teaching the Metric System*, G.G. Bitter, J. L. Mikesell, K. G. Maurdeff, Allyn & Bacon Inc., Longwood Division, Rockleigh, N. J. 07647, 1976, $11.95.
5. *Amusements in Developing Metric Skills*, Alice Clack and Carol Leitch, Midwest Publications, P.O. Box 129, Troy, MI 48084, $4.25.

6. *Cheap Metric Equipment*, Activities and Games, Donald Buckeye, Midwest Publications, (address above), $3.95
7. *Going Metric: Guidelines for the Mathematics Teacher, Grades K-8*, W.W. Lefflin, National Council of Teachers of Mathematics, 1906 Association Dr., Reston, VA 22091, 1975, 48 pp., $1.50.
8. *Happy Metrics I* (Primary), *II* (Intermediate), Blaine and Nelson, Scott Resources Inc., 1900 E. Lincoln, Box 2121, Fort Collins, Colorado 80522. $14.95 ea., $9.95 ea. without three-ring binder.
9. *I'm OK, You're OK, Let's Go Metric*, D. Buckeye, Midwest Publications, (address in #5 above), $4.50.
10. *Let's Play Games in Metrics*, George L. Henderson, L.D. Glunn, National Textbook Co., 8259 Niles Center Rd., Skokie, Ill. 60076, $6.50.
11. *Mathematics*, Geer & Geer, Modern Math Materials, 1658 Albemarle Way, Burlingame, California 94010.
12. *Metric Handbook for Teachers*, J. L. Higgins, National Council of Teachers of Mathematics, 1906 Association Dr., Reston, VA 22091, 144 pp., $2.75.
13. *Metric Measurement Activity Cards*, MCTM Guidelines Committee for Quality Education, Monograph #4, (See address in #2 above), $2.00.
14. *Thinking Metric*, Thomas and Marilyn Gilbert, John Wiley and Sons, Inc., 605 Third Ave., New York, NY 10016, 1973, $2.95.
15. *World of Metric*, Odegard, Sharon E., Gran & Co., 450 W. Algonguin Rd., Arlington Heights, ILL. 60005.

Equipment Checklist

YES?

______ 1. Is the measuring device accurately calibrated? Many suppliers will have information available on the standards to which their equipment is produced. Compare calibrations.

Example: Place meter sticks of two different manufacturers side by side and check that both beginning and ending calibrations agree.

______ 2. Are calibrations permanent or are they apt to wear off (or get scratched off) in a short period of time?

______ 3. Is the device durable? Can it withstand the rigors of child use? Drop it. Squeeze it. Test it.

Example: Styrene, although inexpensive, has a tendency to shatter. Some manufacturers have stopped using styrene for this reason.

______ 4. Does the measuring device fit the use it is being purchased for?

Example: Thermometers with a range of -10 °C to 50 °C cannot be used to find the temperature of boiling water.

______ 5. (Liquid Containers) Children hesitate to fill containers to the top with liquids. Therefore, calibrations should not be made to the very top.

______ 6. Is the device appropriate for the children who will be working with it?

Example: An analytical balance might not be appropriate for early elementary children, however, a simple balance beam might be appropriate.

______ 7. Is it easily repaired? Are parts available?

Example: One of the most expensive pieces of equipment districts will purchase is a pan balance. Replacement pans and parts, which might be broken or lost, should be easily replaced.

______ 8. Is it attractive? Will children want to pick it up and play with it?

______ 9. Can it be used for many applications? Are instructions included?

VII.
A Minimal List of Metric Equipment and Materials

Kindergarten — Third Grades

Quantity	Item	Home Made Alternative Page #'s
8	Combination meter sticks	27
5	Meter sticks scaled only in meters	27
5	Meter sticks scaled only in decimeters	27
5	Meter sticks scaled only in centimeters	27
6-8	Flexible tapes (150 cm long, scaled in centimeters)	27
1	Ten-meter tape scaled in meters and centimeters	27
30	30 cm rulers scaled in centimeters. (Should measure from the end of the ruler).	no alternative
10	Celsius thermometers (range at least -30 °C to 110 °C). (Calibrations should be in 2 °C divisions).	no alternative
2 sets	Metric weights including a kilogram weight. (Metal, plastic or a combination of these).	29
2	Pan balances	30
1	Metric bathroom scale — metric units only preferred	no alternative
2-3	Liter containers (plastic)	31

The items in this list have been determined to be minimal, based on the equipment necessary for instruction of the MDE Minimal Metric Performance Objectives. Quantities are based on those quantities deemed necessary for a unit containing a single kindergarten, 1st grade, 2nd grade, and 3rd grade.
Ideas for the construction of home made equipment which might be used can be found on pages 27-33.

Fourth — Sixth Grades

Quantity	Item	Home Made Alternative Page #'s
15	Meter sticks (scaled in centimeters)	27
30	30 cm rulers scaled in millimeters	no alternative
30	Square centimeter transparent grids (at least 10 cm x 10 cm)	made of transparencies
1 000	Cubic centimeter blocks — plastic, weighing one gram.	no alternative
1	Celsius Room Thermometer (wood back preferred)	no alternative

3	Celsius dipping thermometers	no alternative
10	Celsius thermometers (range at least — 30 °C to 110 °C) Calibrations should be in 2 °C divisions.	no alternative
6-8	Flexible tapes (150 cm, scaled in centimeters and millimeters).	27
1	10 Meter tape scaled in centimeters	27
1	50 Meter tape scaled in centimeters	27
5-6	Pan Balances	30
Ream	Square centimeter graph paper — Or Duplicator Masters for such paper.	
1	Metric bathroom scale. Metric only preferred.	30
1 set	Containers for liquids (1 l, 500 m l, 250 m l as a minimum)	31
1	Dissectible Liter Cube (Cubic Decimeter)	no alternative
10	100 m l graduated cylinders scaled in at least 10 m l divisions. (Soft plastic preferred):	no alternative

Seventh — Ninth Grades

Quantity		Home Made Alternative Page #'s
5	Meter sticks scaled in centimeters	27
30	30 cm rulers scaled in millimeters	27
30	Square centimeter transparent grids (at least 10 cm x 10 cm)	made of transparencies
1,000	Cubic centimeter blocks (plastic ones that weigh one gram preferred)	no alternative
1	Celsius Room Thermometer (wood back preferred)	no alternative
10	Celsius thermometers (range at least -30 °C to 110 °C)	no alternative
6-8	Flexible tapes (150 cm scaled in centimeters and millimeters)	27
1	50 meter tape scaled in centimeters	27
Ream	Square centimeter graph paper or a duplicator master for such paper	
1 set	Containers for liquids (1 l, 500 m l, 250 m l as a minimum)	31
1	Dissectible Liter Cube (cubic decimeter)	no alternative
10	100 m l graduated cylinders (scaled in an least 10 m l divisions) soft plastic preferred	no alternative

VIII.
A Desirable List of Metric Equipment and Materials

Kindergarten — Third Grades

Quantity	
2	Trundle wheel (with clicker, preferably free-turning in either direction)
1	Height measuring device (a "fancy" device). Should be supplemented with a home-made or inexpensively printed height chart in each classroom.
1-2	50 Meter tape (scaled in meters and centimeters)
2-3	Bucket balance
1 set	Cuisenaire Rods (classroom set, in individual containers)

Fourth — Sixth Grades

Quantity	
1	Cubic meter (could be just clips in which to insert meter sticks).
2-3	Spring scales (at least 1 kg, with at least 100 g divisions).
1	Height measuring device (a "fancy" device). Should be supplemented with a home-made or inexpensively printed height chart in each classroom.
2 each	500 ml and 1 000 ml graduated cylinders (Soft plastic).

Seventh — Ninth Grades

Quantity	
2-3	Metric calipers — inside and outside — with spring lock (scaled in centimeters and millimeters).
1	Metric bow calipers (scale on base).
1	Metric depth gauge. May be incorporated on calipers.
1	Surveyor's chain. (Metric dimensions).
30	Geoboards

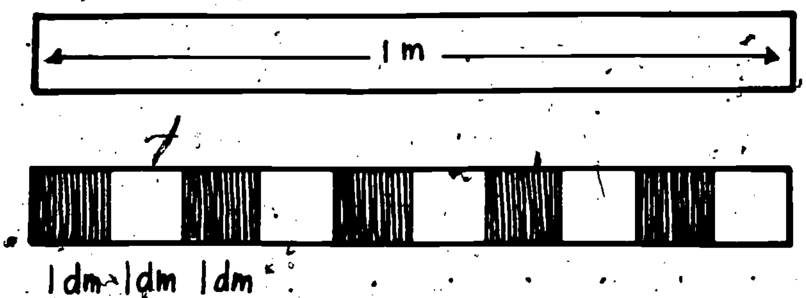
Other Useful Items

1. 5 ml plastic spoons.
2. Weighmix scale. A kitchen scale which can be reset to zero.
3. 50 ml medicine cups. Obtainable from a hospital supply house.
4. Self-adhesive tape marked in centimeters.
5. Paper tape. Adding machine tape will serve well.
6. Metric spoon set. 1, 2, 5, 15, 25, ml spoons.
7. Geoboards.

IX.
Metric Equipment and Materials You Can Make

Measuring Sticks

A school shop class can cut strips of wood (pine) which can be labelled appropriately.



Accuracy: 1. Total length 2 mm at the k-3 level.

2. Decimeter and centimeter markings should be within 1 mm.

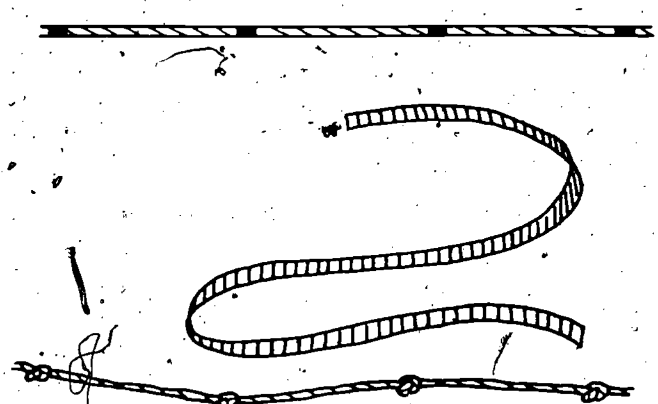
Hint: Use a commercial meter stick to determine the locations of the calibrations.

Distance Measures

Metric tape measures can be constructed of many materials. A list of some of the materials which are frequently used follow:

1. Drapery tape: This material can be torn lengthwise to make several tapes.
2. Adding machine tape.
3. Scrap ends of window shades.
4. Summer lounge chair plastic webbing.

The above materials can be calibrated. Purchase one tape to use as a guide. If no intermediate calibrations are necessary, string or rope knotted at the end points may be all you need.

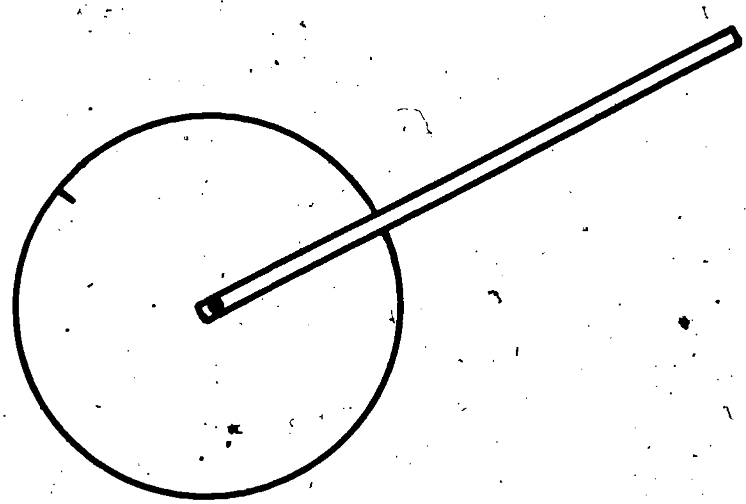


Ropes

Ropes can also be knotted every 20 or 30 centimeters or marked with a felt pen or wrapped with colored tape to make rugged tools.

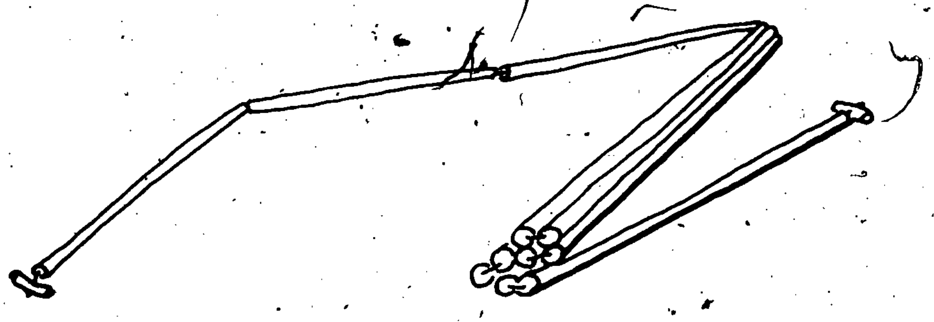
Trundle Wheel

Trundle wheels are fun to make and to use for measuring hallways, playgrounds, classrooms and other big distances. Since the distance the wheel rolls is what is measured, the circumference of the wheel is important. To make a one meter trundle wheel the diameter should be 31.8 centimeters. Make a mark or put a piece of tape on the wheel to help in counting. Attach to a handle with a bolt, nut and washer.



Surveyor's Chain

An interesting metric "surveyor's chain" can be made from large diameter plastic drinking straws (obtained from hamburger stands, school cafeteria or supermarket). The straws should be trimmed in length to a usable metric length, usually 20 centimeters and strung on stout cord until a handy length is reached (say, 5 meters). Tie a short piece (2 cm) of the straw on each end to prevent the cord from slipping through and leave a little slack in the cord so your "chain" bends easily between straws. If you leave enough extra string, the whole thing can be folded into a very compact bundle and held with a rubber band until needed. This device is very nice for comparing perimeters and enclosed areas, or measuring lengths of arm span, height to the nearest 10 cm (by marking each straw in the middle) and other intermediate distances.



Weights

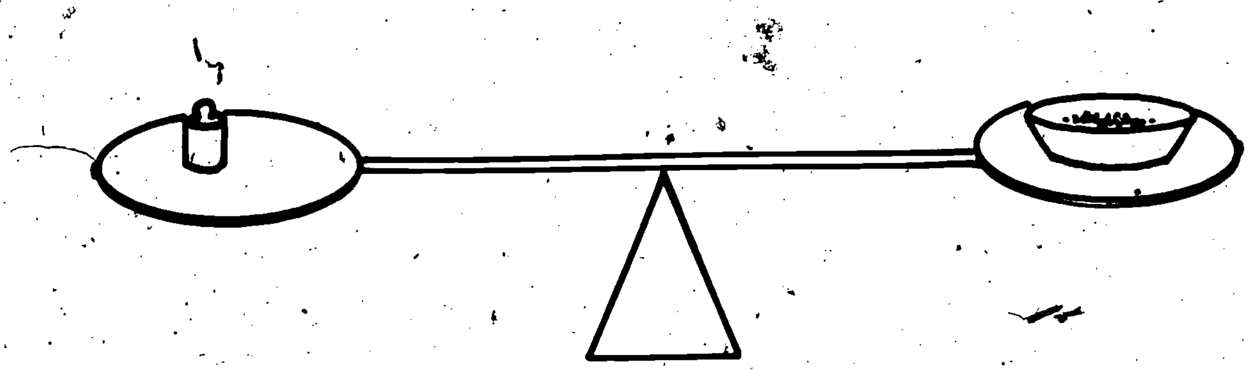
Larger weights can be made quite successfully. Use a good pan balance and an accurate set of weights. With the known weight of one pan fill a

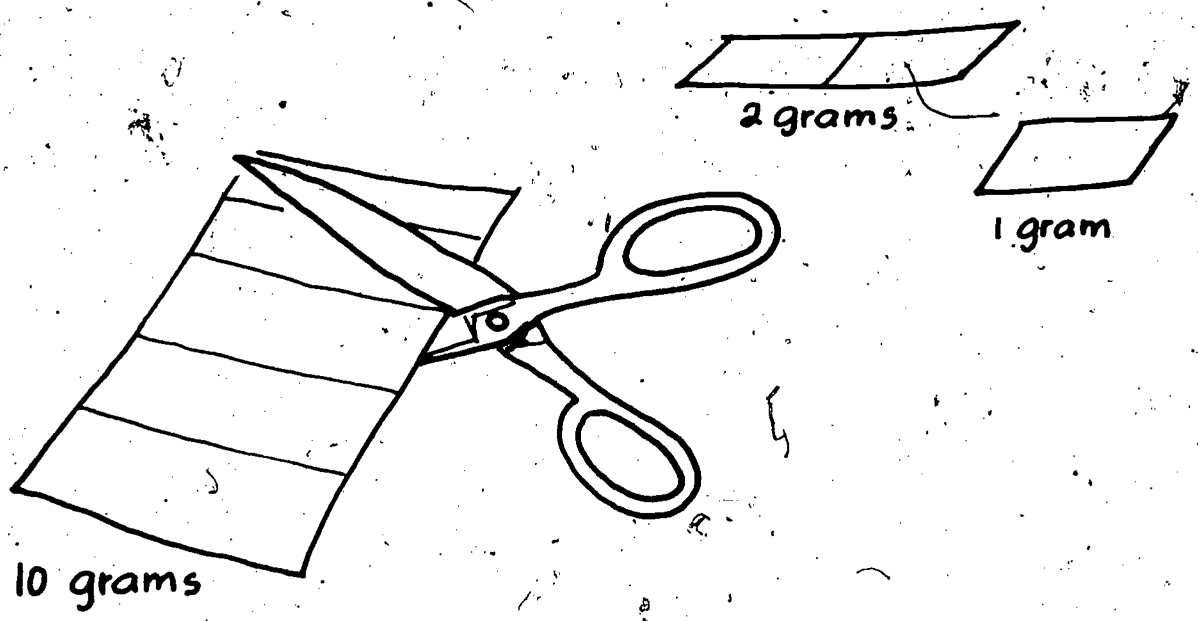
1. 35 mm film container (up to 50 grams or so) or pill bottle
2. zip lock bag (up to a kilogram or so) or canvas bag
3. potato chip or coffee can (more than one kilogram)

with lead shot, dry sand, screws, nuts, or bolts to make the scale balance. Most centicubes have a weight of 1 gram. Many drug stores and film processors will supply you with containers.

Smaller weights can also be made rather easily from scraps of paper or plastic milk cartons. Bits of oil base clay (play doughs lose water and change while drying) are also good.

The simplest procedure is to weigh a large piece and then divide it into smaller pieces. For example, a rectangle of plastic is trimmed with a scissors until it weighs five grams, cutting it into five parts gives us some one gram weights. These can be cut again into still smaller bits to make 100, 200, or 500 milligram weights. LABEL your weights with a marking pen and store in an empty film container or pill bottle.





Pan Balances

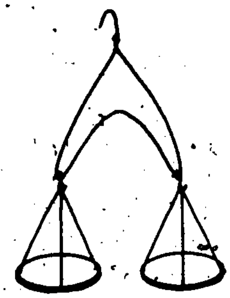
Remembering that a pan balance consists of

(a) 2 pans or buckets (each with three supporting strands)

(b) a balance beam (some allowance for adjustment should be made)

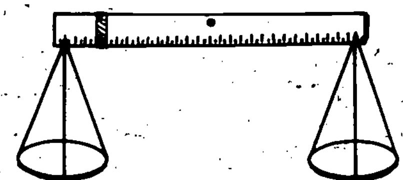
(c) a pivot

you can design and construct your own balance. Three models are shown.



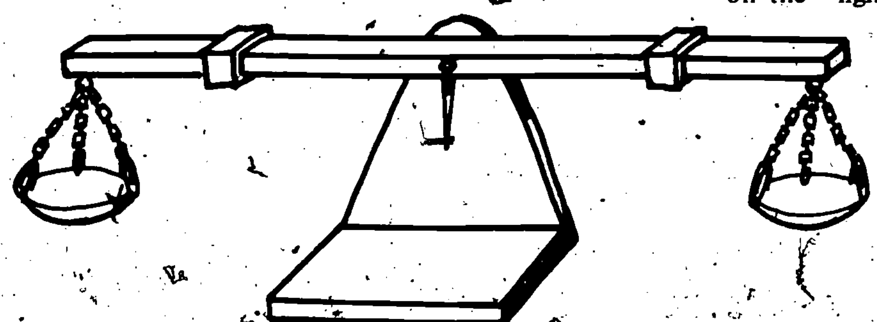
Materials:
coat hanger
s-hooks
string
small dishes

Adjustment:
adjust by bending the hanger



Materials:
drilled metric ruler
bent paper clips
string
small dishes

Adjustment:
adjust by placing tape on the "light" end of the ruler

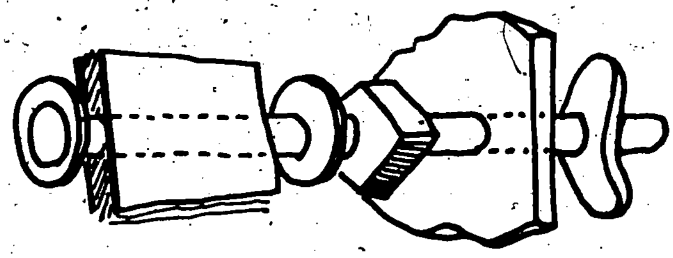


Materials:

1. wooden beam (hardwood)
2. dishes, margarine tubs, "Dairy Queen" dishes
3. light chain
4. Small bolt long enough to go through the balance beam and the supporting board
5. iron wire or finishing nail for the pointer
6. copper wire for balance beam adjustment
7. small screw eyes
8. large paper clips

Instructions:

1. Drill the balance beam just above its center for the pivot and near each end for small screw eyes.
2. Insert the screw eyes and wrap two twists of copper wire around the balance beam. Attach the pointer directly under the pivot hole.
3. Drill each dish and attach it to three pieces of chain (same length) with paper clips. Attach the chains to the screw eyes with paper clips.
4. Mount the balance beam on the base with a bolt through the beam and the base. Mount it as illustrated.



Hints for better operation:

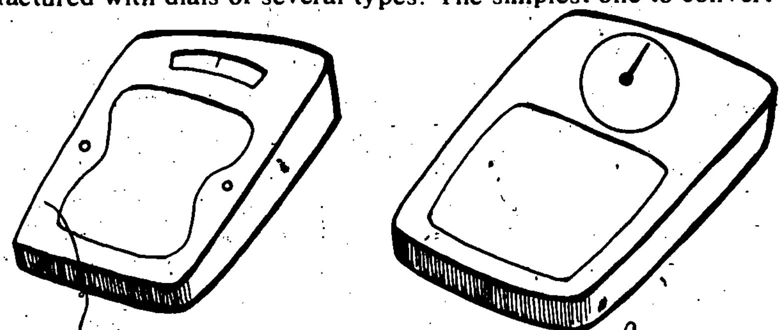
(a) If the bolt is filed into a wedge where it contacts the beam, the balance is more sensitive.

(b) Be sure that the pivot hole is drilled above the center.

(c) Do not "pinch" the balance beam.

Easy Bathroom Scale Conversions

Scales are manufactured with dials of several types. The simplest one to convert is a flat-disk type.

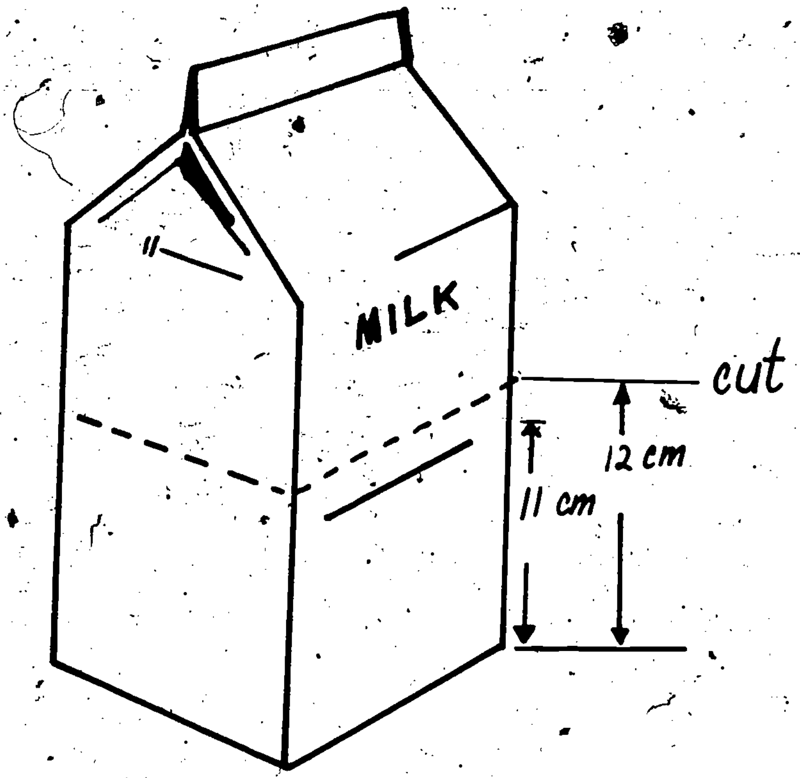


1. Peel back or cut away the nonslip covering on top of the scale. Usually strong springs hold the top in place. Get somebody strong to pull these up and release them from their hold on the top.
2. Lift off the top carefully and set it aside.
3. Remove the dial plate and if ~~the~~ back is plain white, turn it over. If you can't use the back, glue a clean sheet of white paper over the old dial.
4. Recalibrate. Since 2.2 pounds equal 1 kilogram, eleven pounds is five kilograms. Unless you can print small, you can calibrate with five kilogram marks, making a mark over 11, 22, 33, 44, 55, etc. pounds.
5. Replace the top, threading those strong springs loosely through the holes helps. Or tie a length of strong wire to each spring to get it through the top.

Liter Containers

Several containers are very close to being one liter. Any container can be calibrated provided a marked liter container is available. You might use:

1. liter sized soft drink bottles
2. a half gallon milk container cut off at twelve centimeters and marked at eleven centimeters



3. a one pound coffee can
4. a thirty-two ounce automobile oil can (is smaller than one liter).

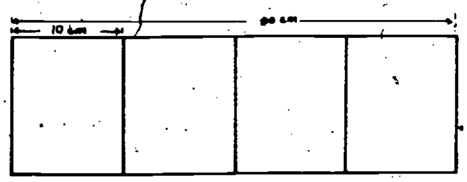
Area Measures

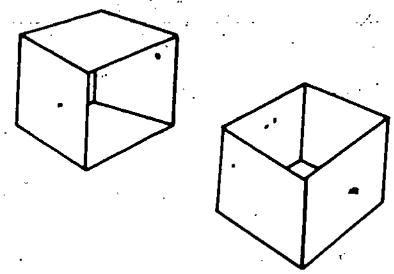
There are many ways of familiarizing children with area measures. The following are a few materials that have been used successfully.

1. A square meter cut from plastic, oil cloth or kraft paper.
2. Square decimeters cut from plastic board, vinyl floor tile, or masonite.
3. Square centimeter paper grids or transparent grids.
4. Tape on the floor or wall to illustrate the size of a square meter.

The Cubic Decimeter
One Thousand Cubic Centimeters

Use two strips of oak tag, 10 cm wide and 42 cm long. Measure, score and fold at 10 cm intervals. Use the remaining 2 cm for a flap to glue or tape to the opposite end of the strip to make a hollow box with no top or bottom.





Fit one hollow box into the other to make a six-faced cube that is one cubic decimeter or the capacity of a liter in size.

Use the model to compare with a cubic centimeter cube and a cubic meter made of meter sticks.

When not is use, remove inner sleeve, flatten each one and store for future use.

Optional:

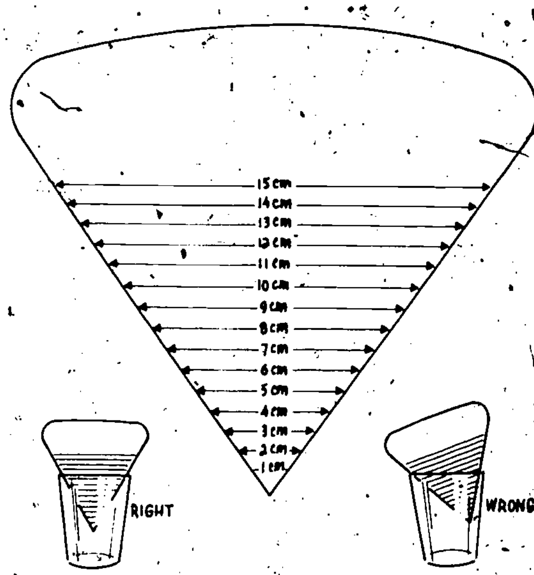
(1) Cut a square 10 cm x 10 cm from centimeter grid paper to cover one or more of the six faces.

(2) Make one hollow box. Fit the other strip inside without gluing the flap. Tape or glue the inner box to the outer one to make a box with a lid.

(3) Line the box with a plastic bag and use to measure the weight of a liter of water.

Diameter Gauge

The diameter gauge is used for measuring internal diameters of objects up to 15 centimeters.

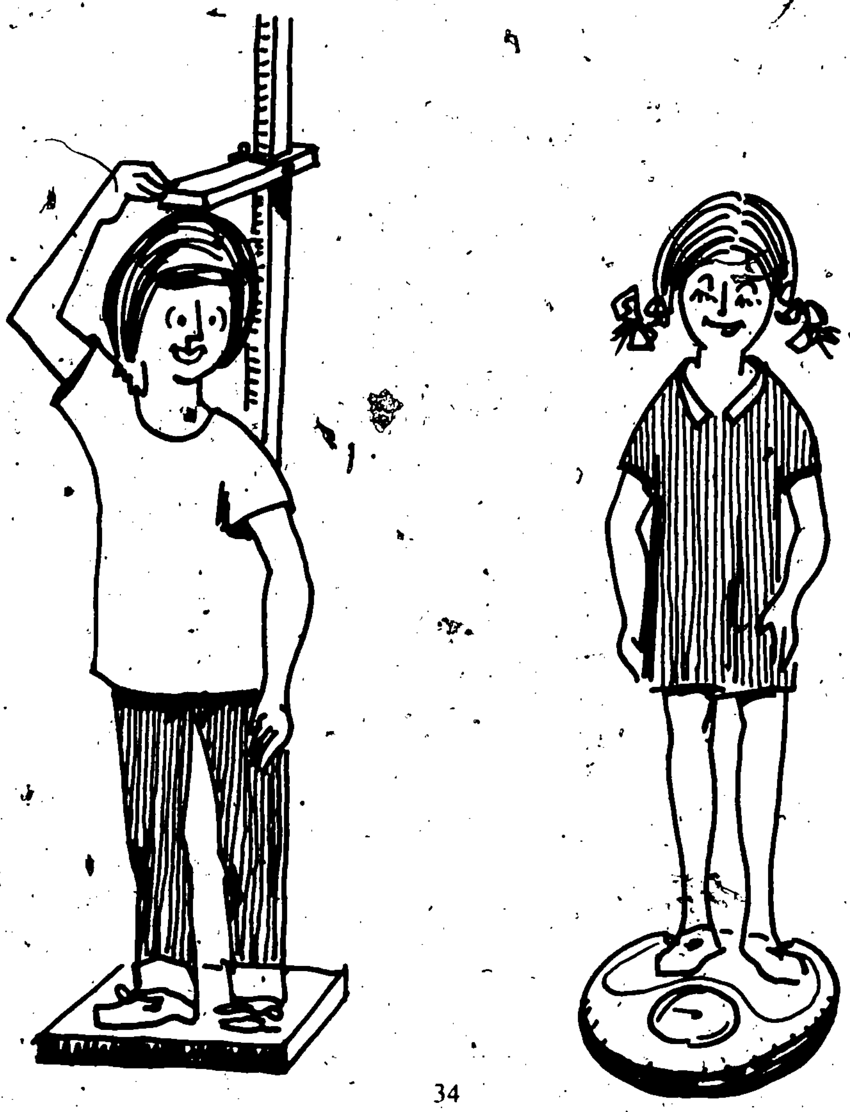


Appendix A
Metric Activities and Games

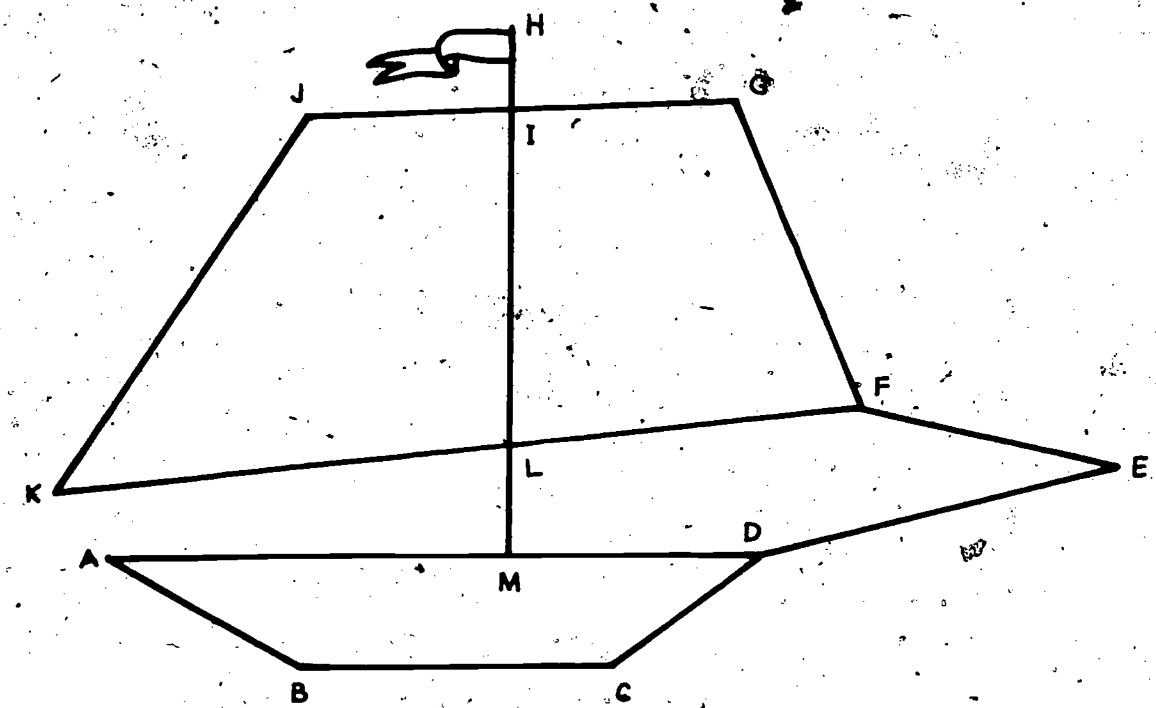
A Metric I.D. Card

Name: ______________________________

Height: ________cm Weight: ________kg
Head: ________cm Waist: ________cm
Neck: ________cm Wrist: ________cm
Foot length: ________ cm

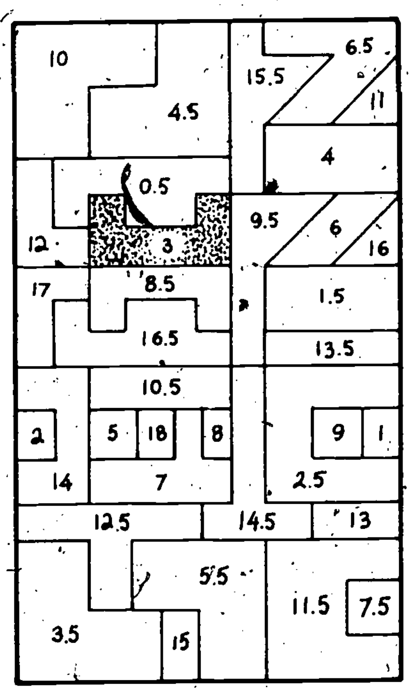


METRIC SAILING



Using a centimeter ruler measure each segment to the nearest 0.5 cm. Then shade in each area that contains an answer. The first one is done.

Segment AB is 3 cm
Segment BC is cm
Segment CD is cm
Segment DE is cm
Segment EF is cm
Segment FG is cm
Segment GJ is cm
Segment JK is cm
Segment KF is cm
Segment AD is cm
Segment HI is cm
Segment LM is cm
Segment HM is cm



Contributed by Dr. Donald Buckeye and Midwest Publications

MATCH-UP

This is a game of challenge. It can be played by an individual or by two individuals working together. The game is played with 9, 16, or 25 cards. Each card has a unit and a value on each edge of the card.

The object of the game is to match edges which are equivalent. Examples: 1.2 kg and 1 200 g, 1 200 m*l* and 1.2 *l*, 1 m and 100 cm, 30 cm and 3 dm.

When the puzzle has been completed all edges must be opposite and equivalent.

		1.2 ml		
		1 200 ml		
1 200 g	1.2 kg		1 m	100 cm
		30 cm		
		3 dm		

3.3 kg 1 cm 1 m 50 mm	5 cm 100 cm 1 l 4.2 m	1 m 1 100 ml 10 m 4 000 g
50 cm 1 m 10 mm 1.2 lm	4.2 m 1 cm .3 m 3.3 kg	4 kg 300 mm 0.3 m 3.2 dm
1 200 m 14 cm 4 dm 10 mm	3 300 g 40 cm 9 cm 1	32 cm 90 mm 10 100 cm

MATCH-UP contributed by Project Metric, Wayne-Westland Community Schools.

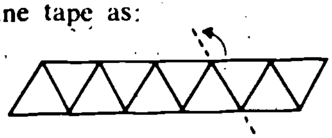
FLEX-A-MATCH

This is a metric equivalence game for two or more persons. It is very similar to MATCH-UP. One player serves as the score keeper. The score keeper reads aloud a phrase for which the other players find an equivalent phrase which has been printed on their flexagon. The first player to find the equivalent phrase earns 1 point. If an incorrect phrase is offered as an equivalent, 1 point is deducted from the person's score.

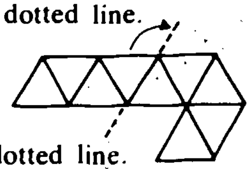
Score Keeper's List	*Equivalents to Place on the Flexagon*
1 *l*	1 000 m*l* or 1 dm^3 or 1 000 cm^3
1 km	1 000 m or 10 000 dm
1 dm	10 cm or 100 mm
37 °C	Body temperature
100 °C	Water boils
20 °C — 40 °C	Room temperature
0 °C	Water freezes
30 °C	Let's go swimming
32 cm	320 mm or 3.2 dm or 0.32 m
Weight of 1*l* of water at approximately 4 °C	1 kg or 1 000 g
1 m^3	1 000 dm^3 or 10^6 cm^3 or 10^{9} km^3
Approximate mass of a nickel	5 grams
Approximate area of a postage stamp	6 cm^2
Approximate diameter of an aspirin	1 cm
Approximate height of a door	2 m
kilo	1 000
hecto	100
deci	0.1
centi	0.01
milli	0.001

FLEXAGON MODEL

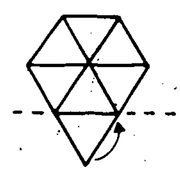
1. Fold adding machine tape as:



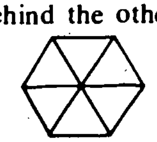
2. Fold under along the dotted line.



3. Fold over along the dotted line.



4. Fold along the dotten line and behind the other end triangle. Glue the two end triangles together.



5. The flexagon can be "flexed" by squeezing two adjacent triangles together and pushing the opposite vertex to form a 3-pointed star. Flexing the flexagon reveals another set of six triangles. There are three sets of six triangles, therefore, eighteen sets of equivalences can be used on each flexagon.

Appendix B
A Brief History of Metric Measurement and Legislation

A. Early Measurement

Early systems of measurement made use of arbitrary (but often descriptive) units of measure. Many of these, such as the cubit, hand, foot, pace, inch, were based on parts of the body. Others, such as the pound, were based on common objects. As such, these measurement "systems" had no common relationship connecting different units. In fact, at first everyone used her/his own foot as a measure. Trade ultimately led to the need for standard units. To convert from standard units to other standard units one had to remember many special numbers or "conversion factors".

B. Major Measuring Systems

As civilization advanced, the crude early measures were incorporated in measuring systems. In more modern times there have been two measurement systems of major importance. The English (Imperial) System developed in Britain. It was based on early English and Roman units and its use spread, with some modifications, throughout the British Empire. The other major system, the Metric System, was invented by French scientists to replace the large number of systems and local measures in France at the time of the French Revolution.

C. History of the Metric System

In 1670, Gabriel Mouton suggested a system of measure based on ten, with the basic unit of length a specified fraction of the length of a great circle on the earth. He called his fundamental unit of length a *metron*.

In 1789-90 meetings, the French Academy proposed the metric system based on Mouton's ideas. The system was based upon the meter which was defined as one ten-millionth of the distance from the North Pole to the Equator, on the meridian passing through Dunkirk, France, and near Barcelona, Spain. (The actual measurement was sightly in error.)

The gram was established as the fundamental unit of mass. It was the weight of one cubic centimeter of water at four degrees Celsius and at standard sea-level pressure.

The metric system was introduced for use in France in 1797. The people did not adopt it rapidly, and Napoleon rejected it. The metric system was reintroduced into trade and commerce in 1837. In 1840 the French government made the use of the metric system compulsory. Soon, use of the metric system, particularly for scientific work, spread rapidly. In 1857 the Treaty of the Meter was adopted by seventeen nations, including the United States. This treaty set up international standards for the meter and kilogram, established The International Bureau of Weights and Measures, and prepared prototypes of the standard meter and standard kilogram.

In 1960 the meter was redefined in terms of a particular wavelength of ionized krypton-86 gas, thus providing an accurate and easily reproducible standard. Also at this time, the International System of Units (Systeme International d'Unites), or the SI metric system was established. The seven fundamental SI units are: the meter, for length; the kilogram, for mass; the second, for time; the ampere, for electrical current; the kelvin, for temperature; the candela. for luminous intensity; the mole, for amount of a substance.

D. Metric Legislation in the United States

In 1790 Thomas Jefferson recommended the adoption of a decimal system of measurement with the fundamental unit the length of an iron rod which, when used as a pendulum, would take one full swing in two seconds. He retained the English names for units, but changed their sizes to conform with his system. However, Jefferson was unsuccessful in getting Congress to accept his plans.

In 1821 John Quincy Adams, acting on earlier suggestions from President Madison, published his classic, *Report Upon Weights and Measures*, in which he set forth the advantages and disadvantages of both the English and metric systems of measure. However, he recommended that for practical reasons, this country continue to use English units.

In 1866 Congress acted to allow the legal use of the "weights and measures of the metric system" in the United States. In 1875 the United States signed the Treaty of the Meter and, as a result, received prototype kilogram masses and meter bars. In 1893 Congress acted to make the metric system the legal standard for length and mass. This meant that the yard would be defined in terms of the meter and the pound in terms of the kilogram.

During the first half of the 20th Century there were several attempts to have metric measure used in the United States. However, these attempts were futile. The first act of consequence was in 1968 when the U.S. Congress authorized a three-year metric study which recommended, in 1971, that the United States set up a coordinated national program for change to the predominant use of the metric system. The most recent legislative activity is the National Metric Conversion Act of 1975.

E. A summary of the Metric Conversion Act of 1975

President Ford, on December 23, 1975, signed into law "The Metric Conversion Act of 1975" (P.L. 94-168), thus ending twelve years of congressional debate as to whether and how the United States should convert to the metric system.

The President's action followed final congressional clearance of H.R. 8674. This bill, which had passed the House on September 5, 1975 was cleared by the Senate with amendments on December 8, 1975. The House agreed to the Senate version without amendment or debate on December 11, 1975.

As signed, the Metric Conversion Act of 1975 declares a national policy of coordinating the increasing use of the metric system in the United States and establishes a U.S. Metric Board to coordinate the voluntary conversion to the metric system. The bill does *not* make conversion to the metric system compulsory, nor does it declare that the metric system shall be adopted as the sole system of measurement in the United States. Instead, the legislation establishes a mechanism for coordinating conversion and for assisting those sectors of society or the economy which voluntarily decide to convert.

A major segment of the bill establishes the U.S. Metric Board to devise and implement a comprehensive program of planning and coordinating the increased use of the metric system. This Board is to include seventeen members, appointed by the President with the advice and consent of the Senate, and representing the groups especially affected by the metric conversion: industry, small businesses, organized labor, standards-making organizations, science, engineering, education, and the consumers.

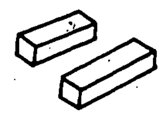
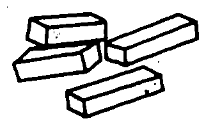
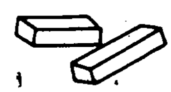
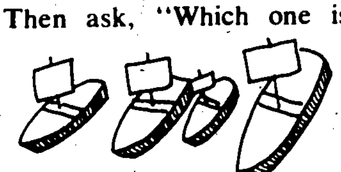
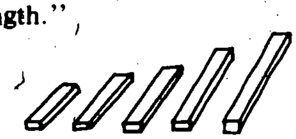
The Metric Board has three major functions:

1. To develop a broad program of planning and coordination;
2. To conduct research and submit recommendations to the Congress and the President on ways to facilitate metric conversion;
3. To conduct a program of public education in the metric system at all levels to familiarize Americans with the meaning and use of metric terminology in their daily lives.

Among the public information and education programs to be supported, the bill specifies that the Secretary of Health, Education and Welfare, the Administrator of the Small Business Administration, and the Director of the National Science Foundation confer with educators and state and local education agencies, to insure that the metric system is included in the curriculum of the country's educational institutions, and that teachers are properly trained to teach the metric system. In addition, the Board will collect, analyze, and publicize information about the extent to which the metric system is being used. The Board is also to conduct reasearch on any unresolved problems associated with the conversion. Subjects that could be researched include the impact of metrication on workers who own their own tools, on small business, or the national security.

Appendix C
A Guide For Writing Learning Sequences in Measurement

The following detailed sequences for learning to measure was developed by Dr. Edward Smith. In preparing specific lesson sequences and curriculum, the tasks and suggested activities should be helpful.

Task Description	*Sample Activity for Length*
A. Perceptual Observation	
1. Nonnumerical measurement Given: a pair of objects an observation procedure "same" and "different" Required: a same/different judgment	Present the learner with a pair of objects (identical or differing only on length) and instructions for observing length. Then ask, "Are these objects the same or different?" 
2. Similarity subset formation Given: a set of objects an observation procedure* a variable name a subset criterion (same/different) Required: a subset of objects meeting the given criterion	Present the learner with a set of objects differing only on length and instructions for observing length.* Then say, "Pick out some objects which have the same/different lengths." 
3. Ordinal discrimination Given: a pair of objects a comparative value (______er) Required: the object described by the given comparative value	Present the learner with a pair of objects differing on length. Then ask, "Which one is longer/shorter?" 
4. Extreme value selection Given: a set of objects an extreme value (______est) Required: the object described by the extreme value	Present the learner with a set of objects differing on length. Then ask, "Which one is longest/shortest?" 
5. Directed seriation Given: a set of objects a variable name Required: the set spatially ordered according to the named variable	Present the learner with a set of objects differing on length. Then say, "Put these in a row according to their length." 

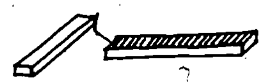
* Each procedure, including reference objects, should be given initially but may be required after sufficient practice.

6. Directed description I-Matching to reference objects

   Given: an object
   a variable name
   an observation procedure*

   Required: a value of the variable which describes the object (in terms of the reference objects)

Present the learner with an object and a set of reference objects. Then say, "Describe the length of this object using this reference object."



7. Operational definition I

   Given: a variable name

   Required: a standard procedure for assigning values of the variable to objects

Ask the learner to, "Describe a standard procedure for determining the length of an object." (Alternative "State an operational definition of 'length' ")

B. Numerical Measurement with Unit Objects

8. Matching to sets of unit objects

   Given: an object
   a variable name
   a set of unit objects

   Required: a subset of unit objects equivalent to the object of the named variable

Present the learner with an object and a set of toothpicks. Then say, "Find a set of toothpicks which has the same length as this object." (Alternative unit objects should be used at different times.)

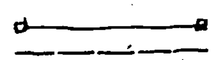
9. Directed description II

   Given: an object
   a variable name
   a measurement procedure*

   Required: a value of the variable describing the object

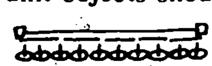
   Procedure a — Matching to arbitrary unit objects

Present the learner with an object and a set of toothpicks. Then say, "Describe the length of this object using toothpick units. Find out how many you can line up beside it." (Alternative unit objects should be used at different times.)



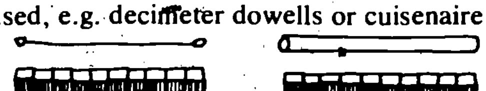
   Procedure b — Matching to combined sets of arbitrary unit objects

Present the learner with an object, a set of toothpicks, and a set of thumbtacks. Then say, "Describe the length of this object using toothpick and thumbtack units. Use as many toothpicks as you can and then as many thumbtacks as you need." (Alternative unit objects should be used at different times.)

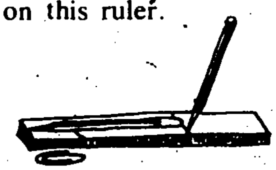
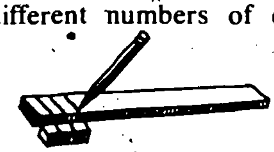
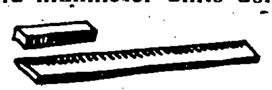


   Procedure c — Matching to sets of standard unit objects

Present the learner with an object and a set of "cubic centimeter blocks." Then say, "Describe the length of this object using centimeter units." (Alternative standard unit objects should also be used, e.g. decimeter dowells or cuisenaire 10 rods.)



* Each procedure, including reference objects, should be given initially but may be required after sufficient practice.

Task Description	Sample Activity for Length
Procedure d — Matching to combined sets of standard unit objects	Present the learner with an object, a set of decimeter dowells, and a set of cubic centimeter blocks. Then say, "Describe the length of this object using decimeter and centimeter units."
Procedure e — Estimation	Present the learner with an object. Then say, "Estimate the length of this object using centimeter units."
10. Operational definition II Given: a variable name an object (optional) Required: a standard procedure for assigning values of the variable to objects	Present the learner with an object. Then say, "Describe a standard procedure for determining the length of an object." (Alternative "State an operational definition of 'length' ")
C. Numerical Measurement with Instruments	
11. Relative comparison Given: a pair of objects a variable name a measurement procedure (for an uncalibrated instrument) Required: a comparative value (______er) appropriately applied to the objects	Present the learner with a pair of objects differing on length and an uncalibrated ruler. Then say, "Compare the lengths of these objects by labeling their lengths on this ruler." 
12. Instrument calibration Given: a set of unit objects a measurement procedure (for an uncalibrated instrument) Required: an instrument calibrated in units corresponding to the unit objects	Present the learner with a set of cubic centimeter blocks and an uncalibrated ruler. Then say, "Calibrate this ruler in centimeters by labeling the length of different numbers of centimeter unit objects." 
13. Directed description III Given: an object a variable name a measurement procedure* Required: a vaule of the variable describing the object	Present the learner with an object and a ruler calibrated in centimeters and millimeters. Then say, "Describe the length of this object in centimeter and millimeter units using this ruler." 
14. Operational definition III Given: a variable name an object (optional context) Required: a standard procedure for assigning values of the variable objects	Present the learner with an object. Then say, "Describe a standard procedure for determining the length of an object." (Alternative "State an operational definition for 'length' ")

The task descriptions remain the same for the other measures: area, volume, weight (mass), force, liquid measure, angle and time. Similar tasks can be developed for temperature, though temperatures do not add in the same way as other measures. To generate a sample activity for another measure substitute the name of the measure, for example, "area" for "length" in the activities in the table.

* A procedure including the instrument and units should be given initially. The units and selection of instrument can be required after sufficient practice.

Appendix D
Activities to Involve the Community

School personnel have an opportunity to assume positions of leadership in acquainting the community as a whole with the movement to metrics. We can cooperate with news media, business and industry to develop understanding and appreciation of the system as it begins to play a greater part in each person's life. Teachers with training and teaching assignments in mathematics and science are most apt to become directly involved because of the nature of the subject matter.

A list of suggested activities follows. No list can be exhaustive but this may serve as a nucleus for planning activities unique to your particular community's needs and interests.

Activities

1. Provide a speakers' bureau prepared with presentations and materials for local groups such as:
   - a. service clubs
   - b. professional organizations
   - c. PTAs
   - d. church/social groups
   - e. YMCA, YWCA, 4-H
   - f. Boy or Girl Scouts
2. Provide news releases, opportunities for pictures, features and programs for the local papers, radio and television.
   - a. Locally prepared, using staff and students.
   - b. Materials distributed from national sources.
3. Arrange for metric displays at local stores and malls, the library, lobbies of Board of Education, court house, city hall, city auditorium or hotels, air, train or bus terminals.
4. A telephone "hot-line" during Metric Week to answer questions concerning metrics.
5. Cooperate with elementary and secondary physical education departments to provide a Metric Field Day in which all events are measured metrically.
6. A Metric Fair can combine games, displays and events with metric awareness — Guess Your Weight (in kilograms) to Centipede Races (in centimeters).
7. During these years of transition, provide a consumer protection service with volunteers acting as "watch dogs" to do some comparative shopping.

   Examples: "Two liters of milk cost me 82 cents. Is that a fair price if two quarts cost 78 cents?"

   2 qts = 1.89 l

   so

   $$\frac{1.89}{2} = \frac{78}{?} \text{ or fair price } = \frac{2 \times 78}{1.89}$$

   or 82.5¢

   "If one pound of hamburger sells for \$1.27, what should I expect to pay for 500 grams?" (500 grams is 1.1 times a pound).

   so a fair price would be 1.1 × 1.27 or \$1.40

8. A metric cooking spree: Make and Eat Workshop. With a gram scale, liter and milliliter measures, Celsius thermometer for oven (if possible) convert some simple, quickly made recipes into metric proportions. The people attending measure, mix and make, eat and enjoy! Cookies and punch make a good combination.

9. Tool up metrically with a make-and-take workshop for the handyman. Measure, cut out, bore holes, fasten, paint and take home a bird feeder, shelf or bird house along with an introduction to metric tools, metric sizing and a blueprint in metric measures.
10. A series of in-service lessons keyed to the needs of a particular group: management level personnel of a local industry, small business associations, production workers or trades group.

    Session I. The relationships of decimal system, monetary system and metric system; background, conversion factors.

    II. Production problems — calculations, tools, machines, packaging, shipping.

    III. Metrics for specific occupations.

    IV. Sessions for planning or practice depending on situation.
11. A metric sewing bee: Make and Wear Workshop.
12. Use billboards, theater marquees, and posters to present Think Metric Tips.
13. Some enterprising young people in one school district erected metric sign posts along bus routes.

Metric Awareness Week

A Proclamation

WHEREAS, The United States and Canada are now adopting the metric system of measurement; and

WHEREAS, Today's children, as adults, will live in a largely metric world; and

WHEREAS, It is the responsibility today of our schools to educate their students for the future; and

WHEREAS, Parents should have an awareness and an understanding of their schools' metric program.

NOW, THEREFORE BE IT RESOLVED, by the Washtenaw County Public School District of Ypsilanti and Eastern Michigan University's declaration that 29 March - April 3, 1976 shall be designated Metric Awareness Week.

BE IT FURTHER RESOLVED that each person shall be encouraged to develop and maintain an awareness of the metric system where applicable in all phases of daily life.

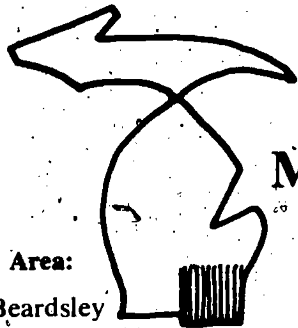
IN WITNESS WHEREOF, we have hereunto set our hands this twenty-second day of March in the year of our Lord nineteen hundred seventy-six, and of the Independence of the United States of America the two hundredth.

Hon. ______________________________
President, Public Schools

Hon. ______________________________
Superintendent, Public Schools

Hon. ______________________________
President,

Appendix E
Metric Resource People



Detroit Area:

Leah Beardsley
11398 Minock
Detroit, Michigan 48228

Rita Brey
18750 Five Points
Detroit, Michigan 48240

Donald Buckeye
Math Department
Eastern Michigan University
Ypsilanti, Michigan 48197

Al Capoferi
19720 Meier
St. Clair Shores, Michigan 48081

Stu Choate
2000 E. Hamond Lake Drive
Bloomfield Hills, Michigan 48013

Terry Coburn
Oakland Schools
2100 Pontiac Lake Road
Pontiac, Michigan 48054

Theresa Denman
1862 Chipping Way
Bloomfield Hills, Michigan 48013

Mary Dinger
3240 N. Range Road
Port Huron, Michigan 48060

LaBarbara Gragg
1700 Kales Building
76 W. Adams
Detroit, Michigan 48226

Petronella Hiehle
2815 Ridgecliffe
Flint, Michigan 48504

Betty Hildebrand
Franklin Jr. High School
33565 Annapolis
Wayne, Michigan 48184

Dave Johnson
747 Skynob Drive
Ann Arbor, Michigan 48105

Otherie Love
18562 Wexford
Detroit, Michigan 48234

Ron Moscow
1100 Surrey Heights
Westland, Michigan 48185

Gail Nordmore
18975 Wildemere
Detroit, Michigan 48821

Sally Ross
23812 Cherry Hill
Dearborn, Michigan 48124

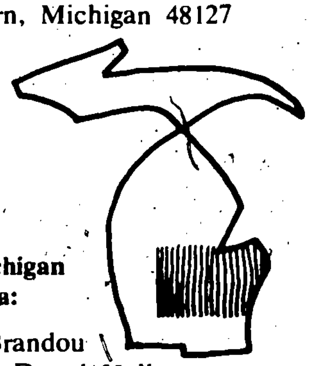
Al Shulte
Oakland I.S.D.
2100 Pontiac Lake Road
Pontiac, Michigan 48054

Tom Yack
Westland Community Schools
646 N. Wayne Road
Westland, Michigan 48185

Valerie Gniewek
11030 Burlington
Southgate, Michigan 48195

Kathy Savage
646 N. Wayne
Westland, Michigan 48185

Charles Schloff
5870 Goldview Dr.
Dearborn, Michigan 48127



Mid-Michigan Area:

Julian Brandou
E 37 McDonel Hall
M.S.U.
E. Lansing, Michigan 48823

Peg Brown
Holt Public Schools
1874 Schoolcraft
Holt, Michigan 48842

Rose Burleson
2513 Wood St.
Midland, Michigan 48640

Ann Fields
103 Human Ecology
M.S.U.
E. Lansing, Michigan 48823

Jean Grey
Saginaw Public Schools
550 Millard
Saginaw, Michigan 48607

Mary Kaufman
South Intermediate School
224 North Elm
Saginaw, Michigan 48602

Dennis Kelly
3943 Bauer Drive, # 9
Saginaw, Michigan 48604

Bruce Mitchell
115 Erickson Hall
M.S.U.
E. Lansing, Michigan 48824

Frank Rogers
Math Consultant
Cedar-Holmes Building
Lansing, Michigan 48910

Mark Straubel
311 Bailey
East Lansing, Michigan 48823

Lauren Woodby
Math Department
M.S.U.
E. Lansing, Michigan 48824

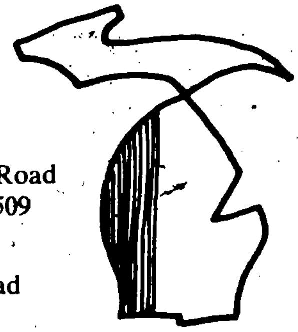
Perry Lanier
201 Erickson
MSU
East Lansing, MI 48824

Daryl Hildreth
2434 Straup Road
Jasper, Michigan 49248

Richard Werstler
Adrian College
Adrian, Michigan 49221

Carl Naegele
E37 McDonel Hall
M.S.U.
E. Lansing, Michigan 48824

Western Portion:



Roberta Bannister
4109-10 Crooked Tree Road
Wyoming, Michigan 49509

Kristine K. Clark
4243 Crooked Tree Road
Apt. 4
Wyoming, Michigan 49509

Patricia Daresh
3131 Creek Drive, S.E. #3B
Kentwood, Michigan 49508

Elsa L. Geskus
249 Alger S.E.
Grand Rapids, Michigan 49507

John Grimberg
6711 Eastern Avenue, S.E.
Grand Rapids, Michigan 49508

Herb Hannon
Math Department
Western Michigan University
Kalamazoo, Michigan 49008

Lou Henkel
W. Ottawa Middle School
3700-140th Avenue
Holland, Michigan 49423

Phil Larsen
Western Michigan University
1105 Evert Tower
Kalamazoo, Michigan 49001

John Lindbeck
Center for Metric Education
Industrial Engineering Technology Bldg.
Western Michigan University
Kalamazoo, Michigan 49001

Michael Meyer
1344 Banbury, N.E.
Grand Rapids, Michigan 49505

Jack Musch
Grand Valley State College
Dept. of Math and Computer Science
Allendale, Michigan 49401

Vern Nyhoff
West Michigan Christian
1212 Kingsley
Muskegon, Michigan 49442

Bill Oosse
5020 Garfield Road
Coopersville, Michigan 49404

Bruce Pearson
3949-168th Avenue
Holland, Michigan 49423

Mary Reed
1070 McAllister
Benton Harbor, Michigan 49022

Jim Riley
Western Michigan University
Everett Tower
Math Department
Kalamazoo, Michigan 49001

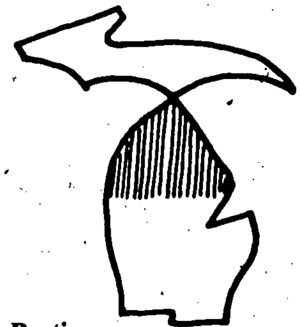
Joe Ryan
1427 Hope St., S.E.
Grand Rapids, Michigan 49506

Marion Saylor
2270 Mapleleaf Terr., N.E.
Grand Rapids, Michigan 49505

Carole Smiley
6246 Pinta Ct., S.E.
Grand Rapids, Michigan 49506

Don VanderJagt
Grand Valley State College
Dept. of Math and Computer Science
Allendale, Michigan 49401

Gerald Woltanski
2300 Rusco Road
Kent City, Michigan 49330



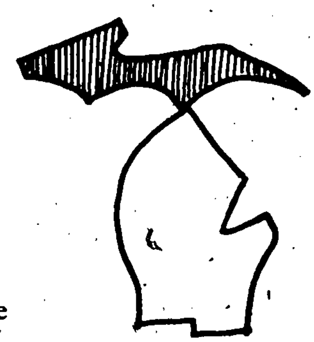
Upper Portion of the Lower Peninsula:

Roy Hajek
319 Lee Point
Suttons Bay, Michigan 49682

Larry Starr
Interlochen Arts Academy
Interlochen, Michigan 49623

Don Strouf
Manistee Senior High School
550 Maple Street
Manistee, Michigan 49660

Dianne Hewitt
Box 243, Rt. 4
Traverse City, Michigan 49684



Upper Peninsula:

John Van Beynen
Math Department
Northern Michigan University
Marquette, Michigan 49855

Dennis Rolando
1701 Barber St.
Bessemer, Michigan 49911

MICHIGAN STATE BOARD OF EDUCATION

STATEMENT OF ASSURANCE OF COMPLIANCE WITH FEDERAL LAW

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